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CONDUCT AND RESULTS OF YF-16 RPRV STALL/SPIN DROP MODEL TESTS

April 1977

Final Report

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AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

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Initial tow qualification tests and parachute recovery system qualification tests were conducted to establish the safety of the helicopter tow/launch technique and to verify the reliability of the parachute recovery system. Three model flights were conducted which demonstrate the feasibility of conducting a research program with extremely limited resources using the remotely piloted research vehicle and the ground control station provided by the Air Force Flight Dynamics Laboratory (AFFDL). When all system over

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components operated properly, the quality of the data acquired was sufficient for real-time control of the model and for post-flight data analysis. Delays caused by extremely unreliable system components and the inordinate time required to repair structural damage sustained by the model during parachute landings caused excessive turnaround times between flights. These delays diminished the frequency of model flights to the point that the small amount of data acquired did not justify the expenditure of resources required, and the program was terminated.

Verification of the validity of drop model testing by comparing stability and control derivatives of the model with those of the full-scale airplane was briefly addressed. Model derivatives were obtained at only one trim condition, and although most derivatives compared favorably, there were significant differences in pitching moment and stabilator trim characteristics. The Drop Model also exhibited a significant decrease in gliding performance. It is concluded that acquiring high angle of attack data for research purposes could be achieved provided certain critical deficiencies in the ground control station and the model instrumentation were corrected.

PREFACE

This report presents the history and results of the YF-16 Stall/Spin Drop Model Project conducted at the Air Force Flight Test Center between January 1974 and September 1976. The authors wish to acknowledge the contributions of the following test team members:

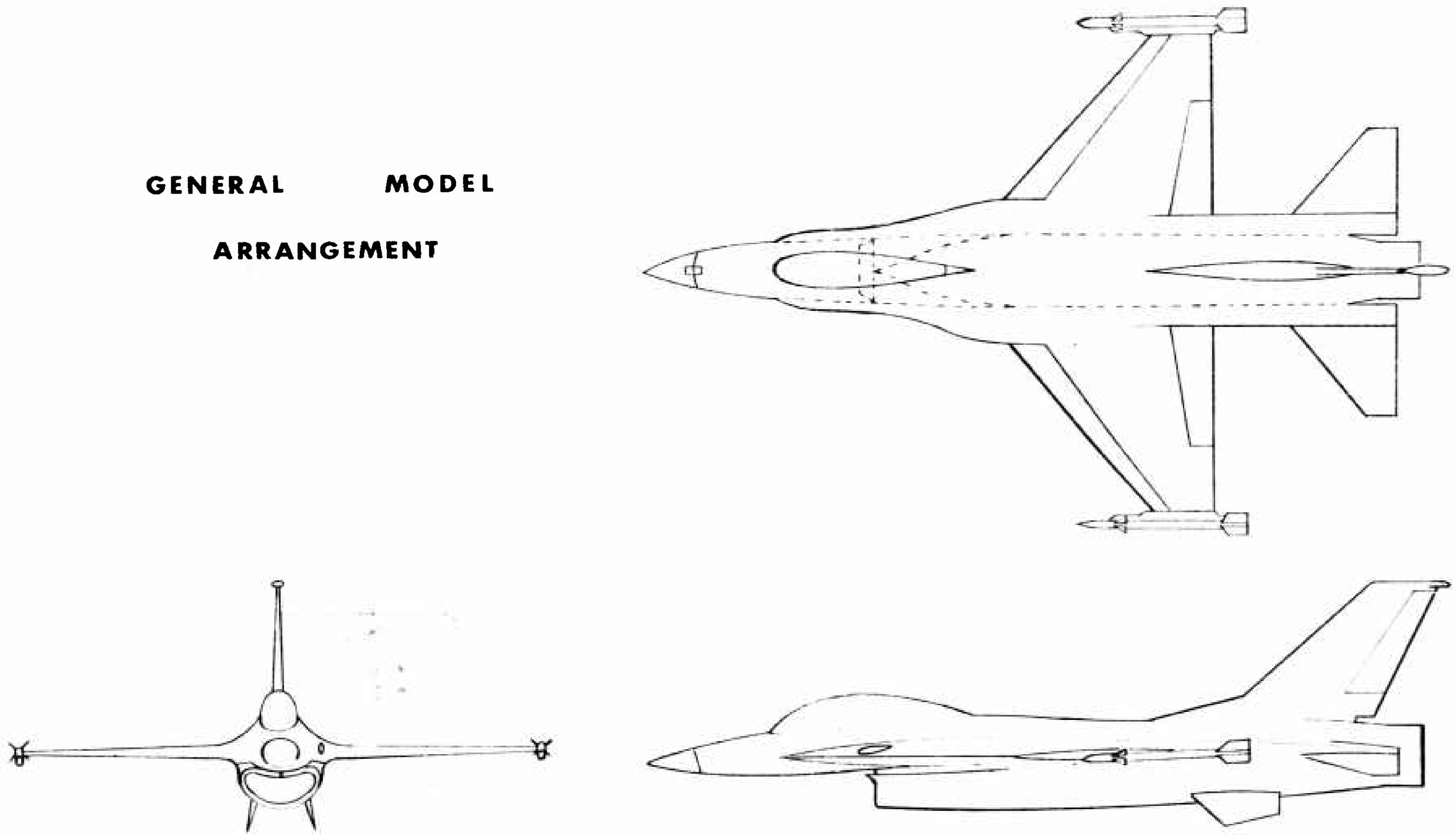
Major Robert P. Barrett	Project Manager/Engineer
Major Edward T. Meschko	Project Pilot
Capt John H. Casper	Project Pilot
1st Lt Edward H. Van Sambeek	Instrumentation Engineer
TSgt Arthur R. Grabb	Instrumentation Technician and Model Crew Chief
Mr. Mark W. Mayes	Instrumentation Technician and Model Crew Chief
Sgt James M. Bell	Instrumentation Technician
1st Lt Larry P. Ray	Simulation Engineer and Computer Programmer
MSgt William D. Walker	Computer Technician
Sgt Edward J. Valls	Computer/Instrumentation Technician and Ground Control Station Crew Chief
Captain Gary M. Rowe	Simulation Engineer

These individuals performed their duties in a thoroughly competent and professional manner. They labored long hours to overcome perplexing technical problems on a low budget, low visibility program and they quite often found themselves expending their efforts well outside their normal areas of responsibility in order to expedite the program.

Special thanks are extended to coauthor, Captain Barry D. Segal, USAFRes, the former Stall/Spin Drop Model Project Manager, for his continued interest and involvement throughout the course of this project and for his invaluable assistance in the preparation of this report.

The authors also wish to acknowledge the advice and assistance obtained from the NASA/Dryden Flight Research Center RPV Projects Office, the Loads Facility, and the Data Systems Engineering Office.

GENERAL MODEL ARRANGEMENT



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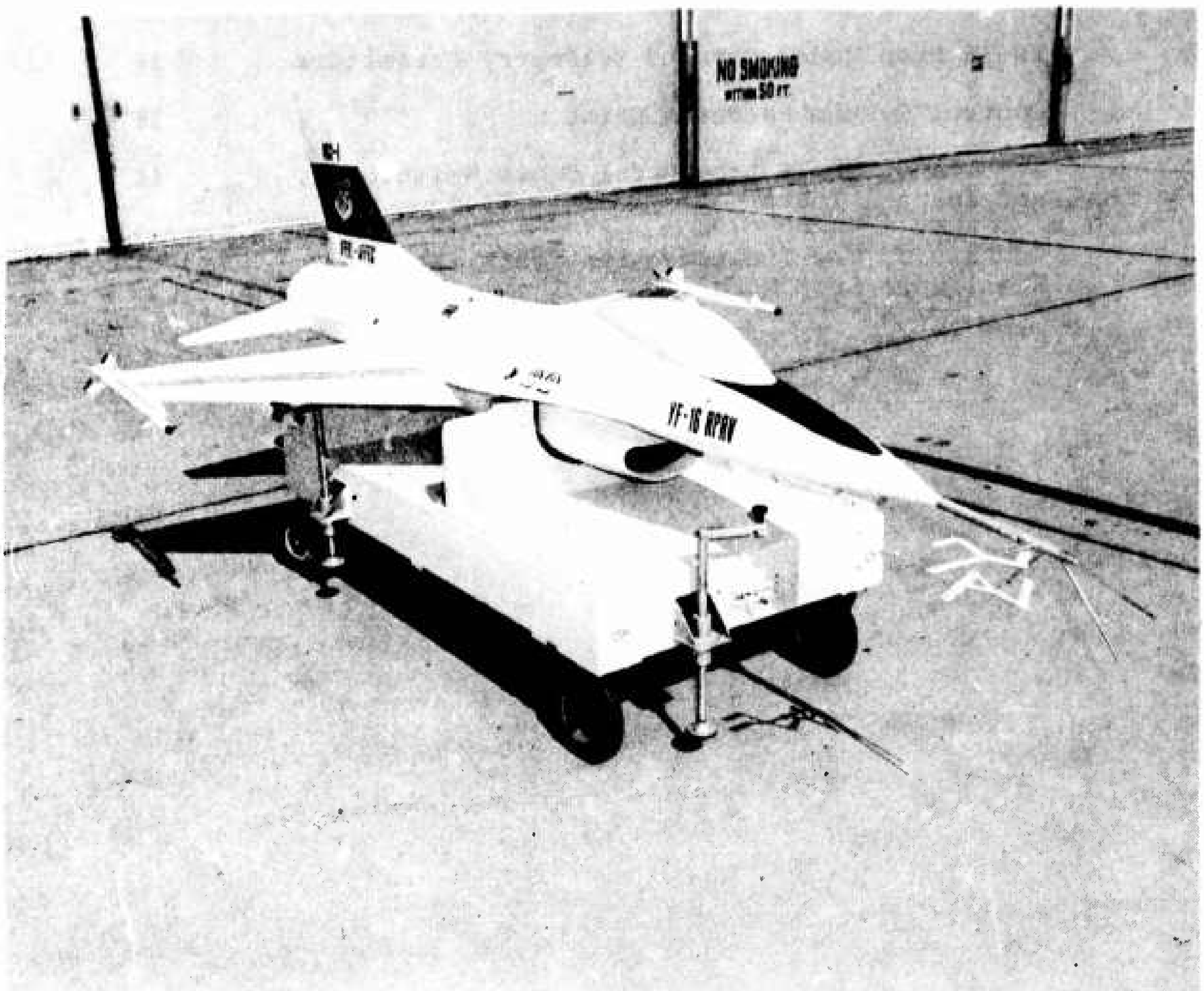

NO SMOKING
YF-16 RPRV

INTRODUCTION

The purpose of this report is to document the history, conduct, and results of the YF-16 Stall/Spin Drop Model Program and to bring to light the conceptual and materiel deficiencies in the program which brought about its early termination.

The model was an unpowered, three-tenths scale YF-16 with an 8-foot, 8-inch wingspan and a weight of approximately 900 pounds. Sensors aboard the model provided information for telemetry of those parameters required by the pilot on the ground to control the model and for post-flight data analysis. Proportional commands from the pilot's control stick and rudder pedals were summed with preprogrammed control laws in a ground based computer and the resulting control surface commands were telemetered back to the model. The model was freely suspended beneath a UH-1N helicopter from a 25-foot cable and towed to a launch point above 16,500 feet pressure altitude. The model was released and testing was accomplished during a glide to 6000 feet where the parachute recovery sequence was initiated.

PROGRAM OBJECTIVES

The program was intended to develop high angle of attack technology and to provide an increased capability for experimental flight testing through the use of small, remotely piloted, dynamically scaled models. When it was first conceived by the Air Force Flight Dynamics Laboratory (AFFDL), the program was intended to provide a technology base for the solution of problems concerning high angle of attack flight. Specific objectives of the program were:

1. To obtain flight data at high angles of attack to acquire linear and nonlinear stability and control derivatives in the prestall, stall and post-stall flight regimes.

2. To identify those parameters which become effective in influencing aircraft flight characteristics in the prestall, stall, and post-stall flight regimes.

3. To verify the validity of the drop model technique by comparing the stability and control derivatives and the post-stall gyrations of the model with those of the full-scale prototype aircraft.

4. To determine the minimum expenditure required to accomplish the above objectives.

Flight test operations were to be conducted at Edwards AFB by the prime contractor with a minimum of participation by the Air Force Flight Test Center (AFFTC). When it became evident that the contractor would not be able to conduct the flight test program in a timely manner, the AFFTC accepted responsibility for systems development and test operations and the scope and objectives of the program were narrowed. The AFFTC agreed to conduct a limited flight test program with the following objectives:

1. To evaluate the feasibility of conducting a program using a helicopter launched, parachute recovered, low cost remotely piloted research vehicle (RPRV) for high angle of attack flight testing.

2. To evaluate the quality of the data which can be acquired using this approach.

3. To submit all the data acquired to the AFFDL for their subsequent analysis.

PROJECT BACKGROUND

The Drop Model Project was originally conceived in 1971 by the Air Force Flight Dynamics Laboratory as a low cost method of conducting research in high angle of attack flight, and spin characterization. The validity of this research technique was to be proven by comparing model flight test data with full-scale YF-16 flight test data.

It was the emphasis on low cost which drove the selection of equipment and the development and integration of the various systems and subsystems (low initial acquisition cost) and the selection of the helicopter launch and parachute recovery techniques (low operational cost).

The program was to be primarily a contractor effort in which the contractor was to design, manufacture, and maintain the entire system and perform all flight testing. The Air Force Flight Test Center (AFFTC) was to provide launch and chase aircraft and crews and the model pilots, as well as the required support facilities: communications, data recording, airspace, radar and optical tracking, model recovery equipment, maintenance shop space, and all normal utilities. Primary data reduction and analysis, as well as correlation with full-scale YF-16 flight test results, were to be performed by the contractor.

AFFTC personnel envisioned the eventual development of a low cost, low risk technique of determining departure and spin characteristics, as well as spin avoidance and recovery techniques, prior to initial flight testing of prototype or development aircraft.

In late 1972, the AFFDL negotiated a $950,000 Drop Model contract with Atkins & Merrill, Inc. (A&M), of Ashland, Massachusetts, and Tulsa, Oklahoma, calling for the development, production, and checkout during 1973 of all Drop Model systems hardware: one ground control station, two weighted cylinders (Iron Bombs) for initial parachute recovery system tests, one uninstrumented YF-16 model (Iron Bird) for helicopter tow qualifications and final parachute system qualifications, two complete YF-16 models, and two complete YF-17 models. The contractor was to perform 25 flight tests on the two YF-16 models and 25 flight tests on the two YF-17 models between January and June 1974.

The contractor fell behind schedule almost immediately. Initial parachute system tests were delayed from October 1973, to December, then to March 1974. Cable tow qualification and model tow qualification tests were conducted in late March, but a failure in the first parachute test resulted in further delay. Successful low speed and high speed Iron Bomb parachute deployment qualification tests were conducted on 21 June 1974 and 24 June 1974, respectively. Similar low speed and high speed Iron Bird deployment tests were flown on 25 June 1974 and 2 July 1974; both were successful.

In June 1974, Atkins & Merrill declared a cost overrun condition, and the contract was renegotiated to halt production of the YF-17 models and delete that portion of the flight test program. The two YF-16 models were delivered to Edwards AFB in October 1974, but they required additional systems integration and functional checkout, and complete calibrations

of all instrumentation sensors. Because the program was so far behind schedule, the AFFDL requested that the contractor deliver the ground control station in November 1974 before he had completed development work on it. The transfer of information between the cockpit, the telemetry systems, and the computer had never been attempted and none of the computer programming had been completed. The telemetry link between the ground control station and the model had never been established.

Most of the contractor's efforts were directed toward developing the ground control station interface system and programming the computer. When problems arose, it was difficult to determine whether they were generated by computer programming errors, interface system malfunctions, or improper operating and troubleshooting procedures. Because the development was being completed at Edwards AFB, certain equipment and facilities were not available to the contractor personnel. The computer programmer returned frequently to Tulsa, Oklahoma, to assemble major corrections and modifications to the program. Without a functioning computer program and proper test equipment, progress on correcting interface system deficiencies was seriously hampered.

The efforts of the AFFTC instrumentation personnel were directed toward calibration of model instrumentation sensors and learning the model checkout procedures established by the contractor. Both the instruction and the documentation provided by Atkins & Merrill for proper handling and checkout of the model systems were inadequate. Vital points concerning the operation of the model control logic and the parachute deployment logic were omitted. A&M intended to accept the calibrations provided by the vendors of the various instrumentation sensors without rechecking them or calibrating them as installed in the model. It was probably A&M's inexperience with flight-qualified systems which prompted this decision. To correct this situation, AFFTC instrumention personnel expended many man-hours designing and fabricating fixtures and developing methods for calibration of the attitude reference gyros, the angular accelerometers, and the linear accelerometer/rate gyro packages. Of the twelve units (four of each type), only one angular accelerometer unit and one attitude reference unit were found to be operating properly; the other units were returned to the vendors for repair. Some of these units were returned as often as three times through the course of the project.

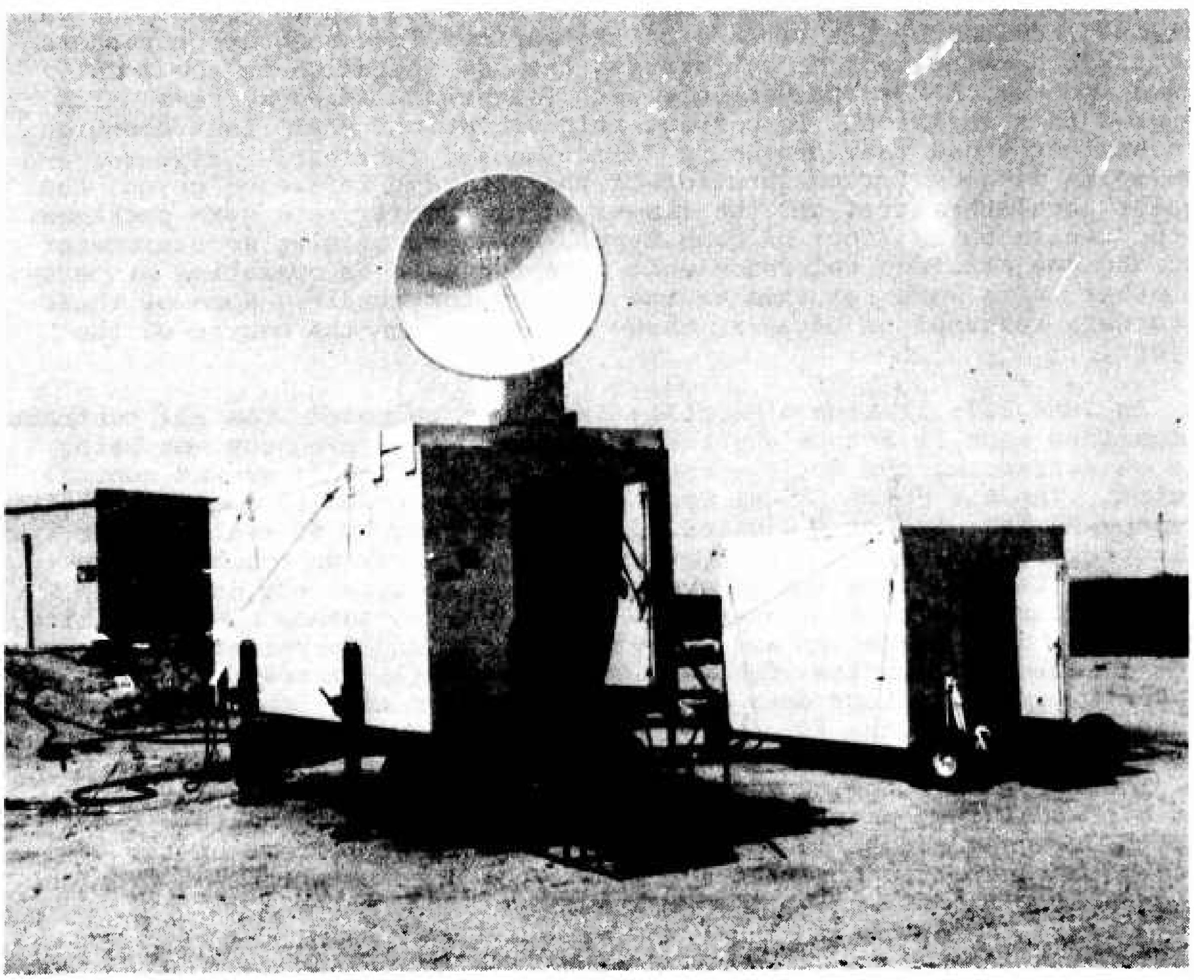
In June 1975, Atkins & Merrill, Inc., was released from all contract obligations when it became apparent that no further progress was being made on correcting the deficiencies which existed in the ground control station. The Air Force Flight Test Center then agreed to continue systems development and conduct a limited flight test program to evaluate the helicopter launch, parachute recovery, low cost RPRV approach to high angle of attack testing and to evaluate the quality of the data which can be acquired using this approach. AFFDL was to assume responsibility for primary data reduction and analysis efforts and correlation of Drop Model flight test results with full-scale YF-16 flight test results. The AFFTC was to monitor data quality and perform only that data analysis necessary to update the flight planning simulator.

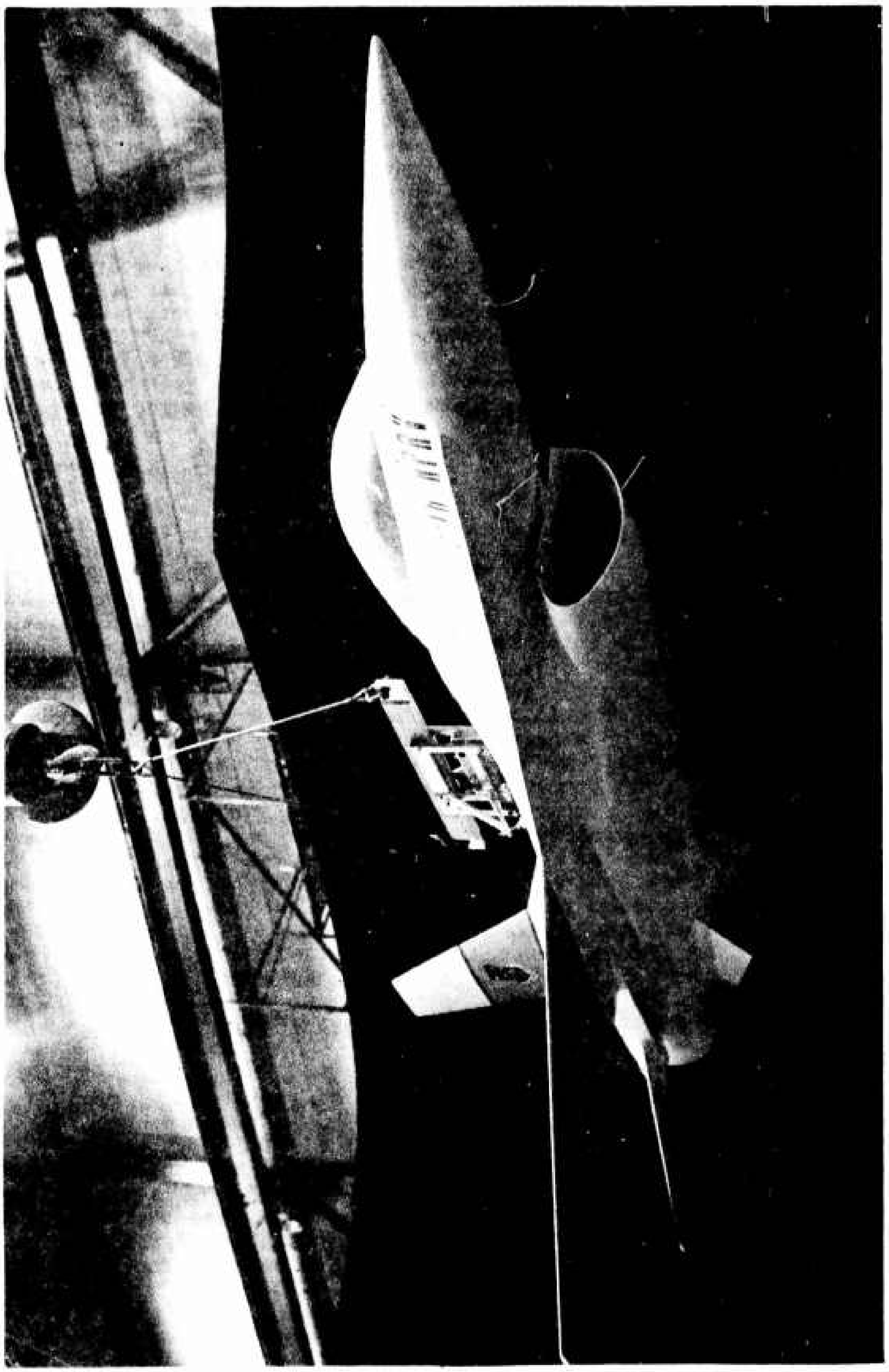
The AFFTC development efforts were severely hampered by the fact that the contractor provided very little documentation on either the systems designed and built specifically for this project or on the systems subcontracted to other vendors. What documentation was provided was generally incomplete or inaccurate.

FLIGHT TEST SUMMARY

Actual flight test operations consisted of three Iron Bomb parachute recovery system development tests, four Iron Bird helicopter tow qualification test, one model tow qualification test, three Iron Bird parachute recovery system verification tests, three captive tests with the fully instrumented model, and three free-flight, controlled flight tests.

The first attempt at controlled free flight was made on 3 October 1975. It lasted 69 seconds because the model control logic drove all the control surfaces to the streamlined position and the model became uncontrollable. The second flight, conducted on 8 May 1976, lasted 3 minutes, 35 seconds, and disclosed deficiencies in model performance, uplink telemetry, and certain data sensors. Control of the model and operation of the parachute recovery system were satisfactory. The third flight, conducted on 31 July 1976, lasted 3 minutes 24 seconds and verified the deficiencies noted on the second flight. Some of the more serious data acquisition problems had been rectified prior to the third flight, which permitted calculation of model performance parameters between 7 and 16 degrees angle of attack (α) and extraction of both longitudinal and lateral directional stability and control derivatives at 9 degrees angle of attack.





YF-16 DROP MODEL SYSTEM DESCRIPTION

Figure 1 presents a schematic diagram of the YF-16 RPRV system. Data recording and real time data display were provided by the AFFTC data acquisition facility; radar and optical tracking and control were provided by the AFFTC Space Positioning Optical and Radar Tracking (SPORT) facility. While they were both integral parts of the Drop Model system, they were not unique to this project and will not be described below; only their respective functions and products will be described under Typical Flight Operations in a subsequent section of this report.

Except for a small amount of government furnished equipment (GFE), all other components and systems originally used on this project were manufactured or purchased by Atkins & Merrill under contract to AFFDL. Some of these components were replaced or modified by AFFTC personnel as the project progressed. The condition of each system as it was delivered by the contractor, and the evolution of the system through the course of the program, will be described in the following sections.

THE MODEL

Basic Construction:

The flight vehicle used on this program was a three-tenths scale model of the YF-16 lightweight fighter prototype. The Drop Model fuselage construction consisted of a fiberglass shell and an internal aluminum structure composed of five machined bulkheads connected by longitudinal structural beams. The internal structure supported the onboard instrumentation, electrical, and hydraulic flight control systems, and offered hard points for the launch-rack attachment, vertical tail, horizontal stabilators, and the wing root attachments. The parachute recovery system was housed in an aluminum cylinder in the "engine bay". The fuselage fiberglass skin was molded in four sections, (top forward, bottom forward, top aft, and bottom aft sections). The sections were bolted to the internal aluminum structure and subsequently bonded together and to the aluminum. The forward and aft sections were joined at the midpoint of the wing root, and the top and bottom sections were joined at the midpoint of the fuselage (at the strakes forward of the leading edge of the wings). The forward 18.5 inches of the fuselage, including the pitot boom, was hinged at the top to allow the nose section and the pitot boom to swing up to an almost vertical position. Since the model landed beneath the recovery parachute in a horizontal attitude, the pitot boom was less likely to suffer damage on touchdown. The nose section was spring loaded to the "up" position and mechanically latched to the normal "down" position.

The model underbelly was constructed of low density, rigid foam designed to crush on impact and attenuate the landing shock. It was covered by a fiberglass skin which was bolted, but not bonded, to the fuselage fiberglass and the aluminum structure. The bolt heads and other blemishes at the juncture of the fuselage and underbelly fiberglass were then filled with putty and sanded smooth to duplicate the full-scale YF-16 external contours. The air intake was completely blocked by the foam except for a 2-inch diameter cooling air passage for the hydraulic pump.

The wings were constructed of a wood spar and a foam-filled aluminum honeycomb, sandwiched between fiberglass skins. The wing roots were

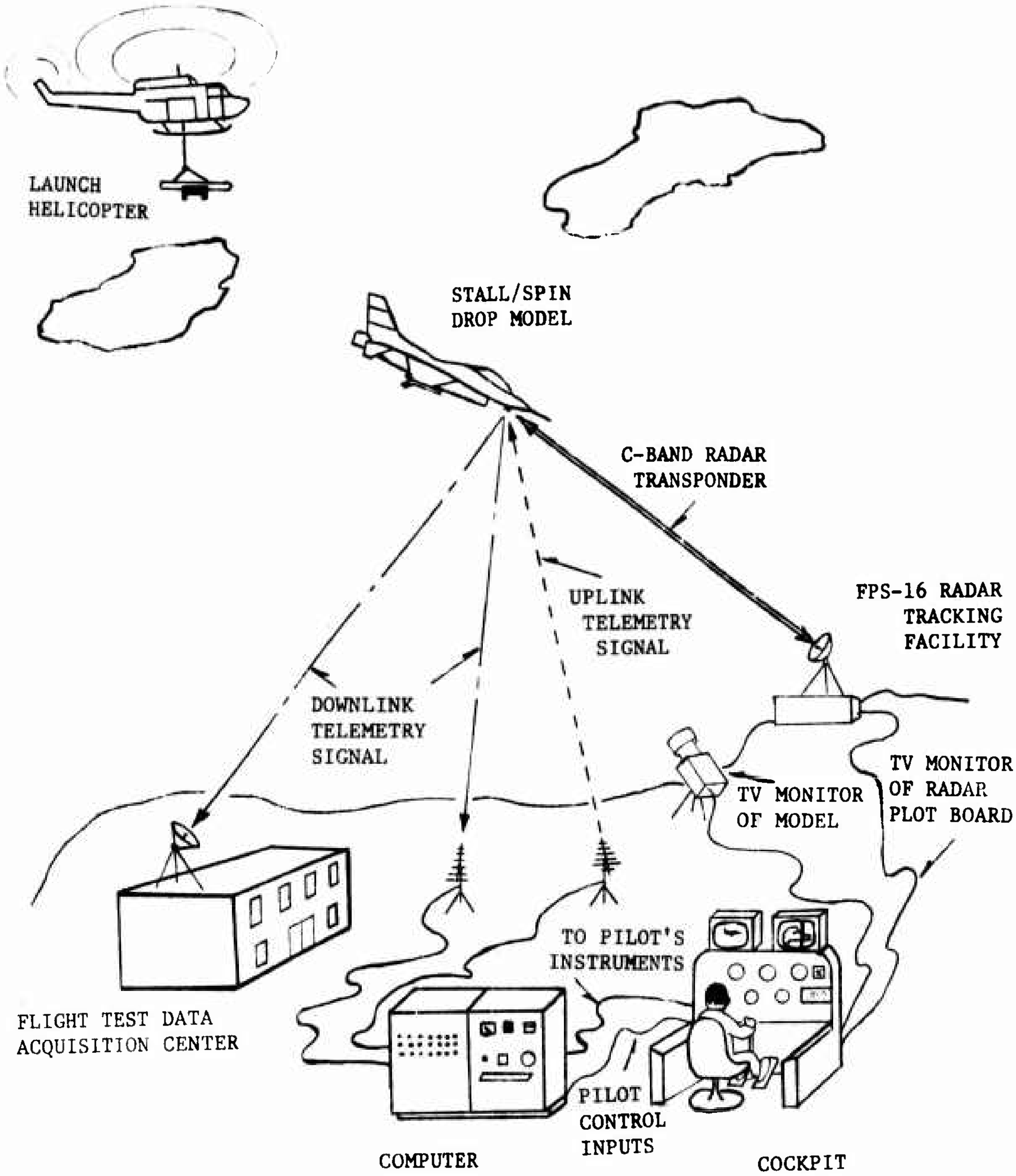


Figure 1 A Schematic Diagram of the YF-16 RPRV System

machined aluminum fittings bonded in the wing skins. The wing leading edge flaps were ground adjustable to 0 degrees, 12.5 degrees, or 25.0 degrees (with respect to the model x axis) by removable, recessed aluminum brackets. Simulated AIM-9 missiles and launch rails were bolted to attachment points bonded into the wingtips. The flaperons were fiberglass skins covering a foam core, and were supported by two hinges on the wing and a pivot bracket at the flaperon root. The maximum flaperon deflection was ±20 degrees.

The vertical tail and rudder and the horizontal stabilators were fiberglass skin with a foam core and aluminum root structure. The stabilator pivot assembly was attached to a structural bulkhead; maximum stabilator deflection was ±25 degrees. The rudder was supported by two hinges in the vertical tail and a structural pivot bracket at the rudder root; maximum rudder deflection was ±30 degrees. All moving control surfaces were attached to linear hydraulic servoactuators with a bell crank arrangement. Figure 2 presents the sign convention used throughout the Drop Model program.

The model was designed to be launched from a modified MA-4B bomb rack, also called the launch rack mechanism. The launch-rack mechanism was attached to two spring-loaded fittings at the top of the model fuselage and was stabilized with two adjustable sway braces. The mechanism could be adjusted so that the model would hang at pitch angles from -15 degrees to +10 degrees under static conditions (zero airspeed).

Notes: 1. About each axis a positive force produces a negative surface deflection and causes a positive moment.
2. For each individual flaperon and stabilator flight control surface TED is positive and TEU is negative.

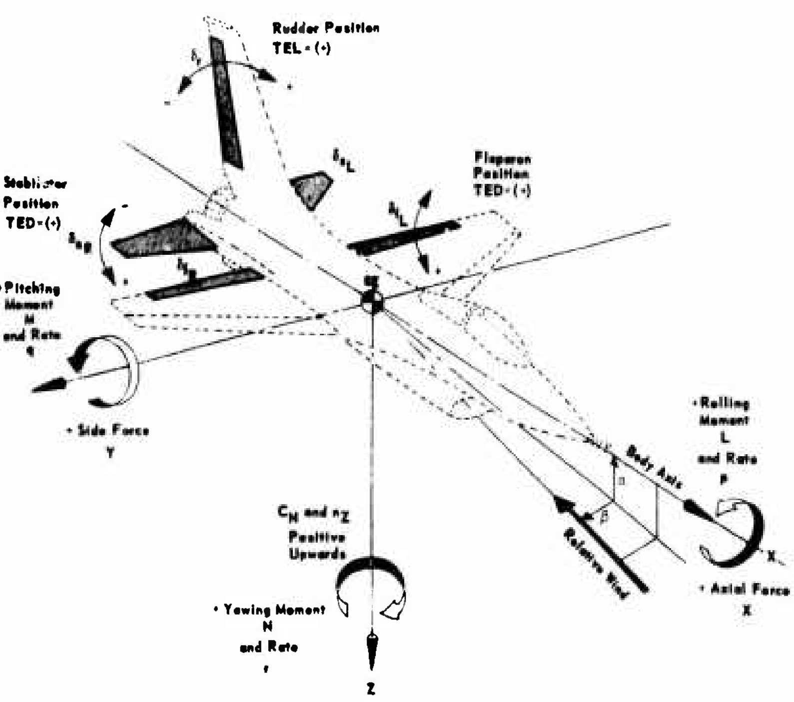
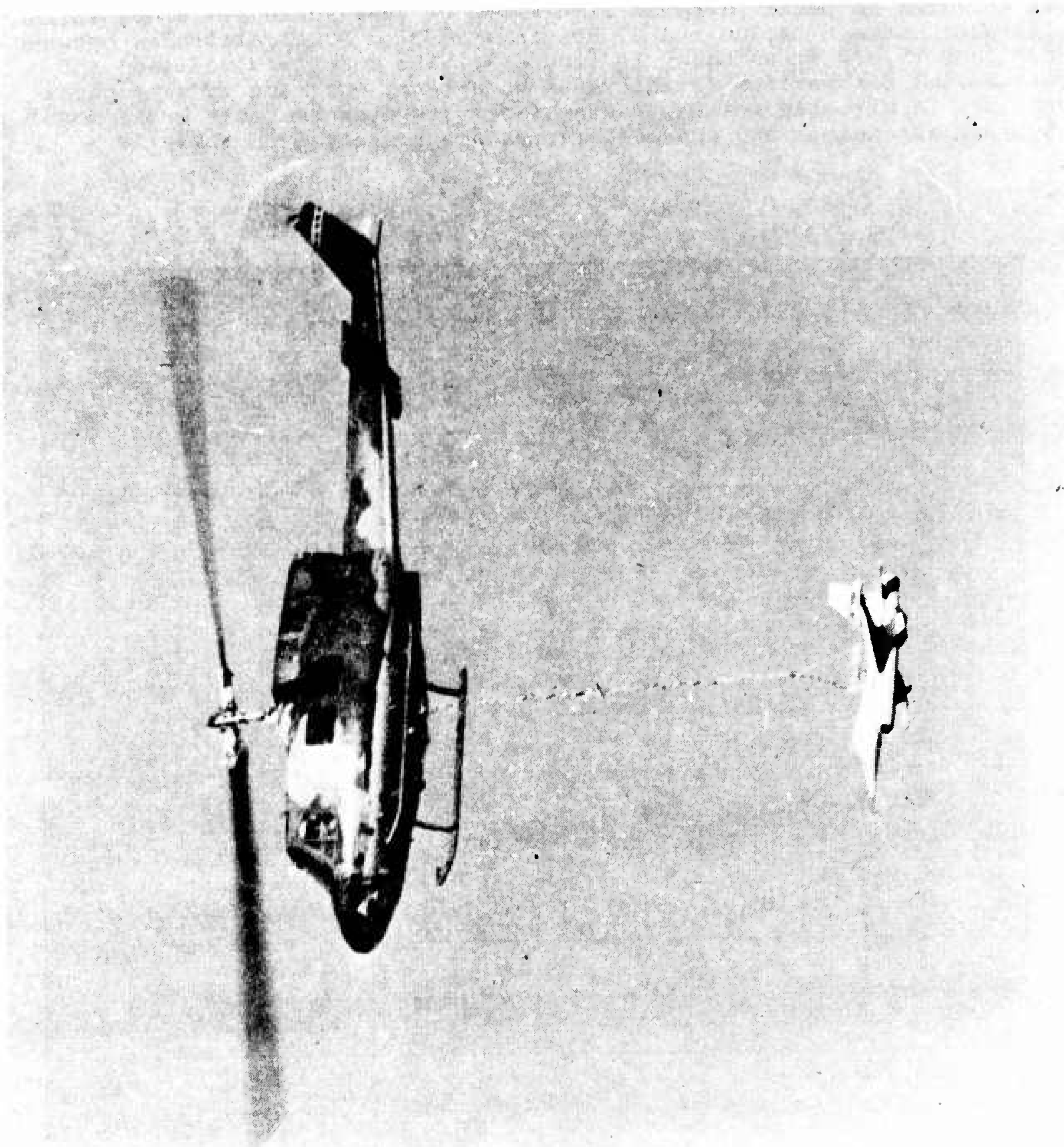


Figure 2 YF-16 Drop Model Sign Convention



The model was statically balanced to approximate a longitudinal center of gravity (cg) location at 35 percent mean aerodynamic chord (MAC). It was dynamically balanced to provide Froude number scaling and altitude scaling as described by Woodcock[1]. A model design altitude of 20,000 ft was selected to permit dynamic simulation of full-scale YF-16 operating altitudes between 24,300 and 32,900 ft with Drop Model altitudes between 5000 and 15,000 ft as shown in figure 3. The model was designed and constructed for maximum rigidity and no attempt was made at structural scaling. Applicable scaling factors are presented in table 1 and model physical dimensions and characteristics are presented in table 2.

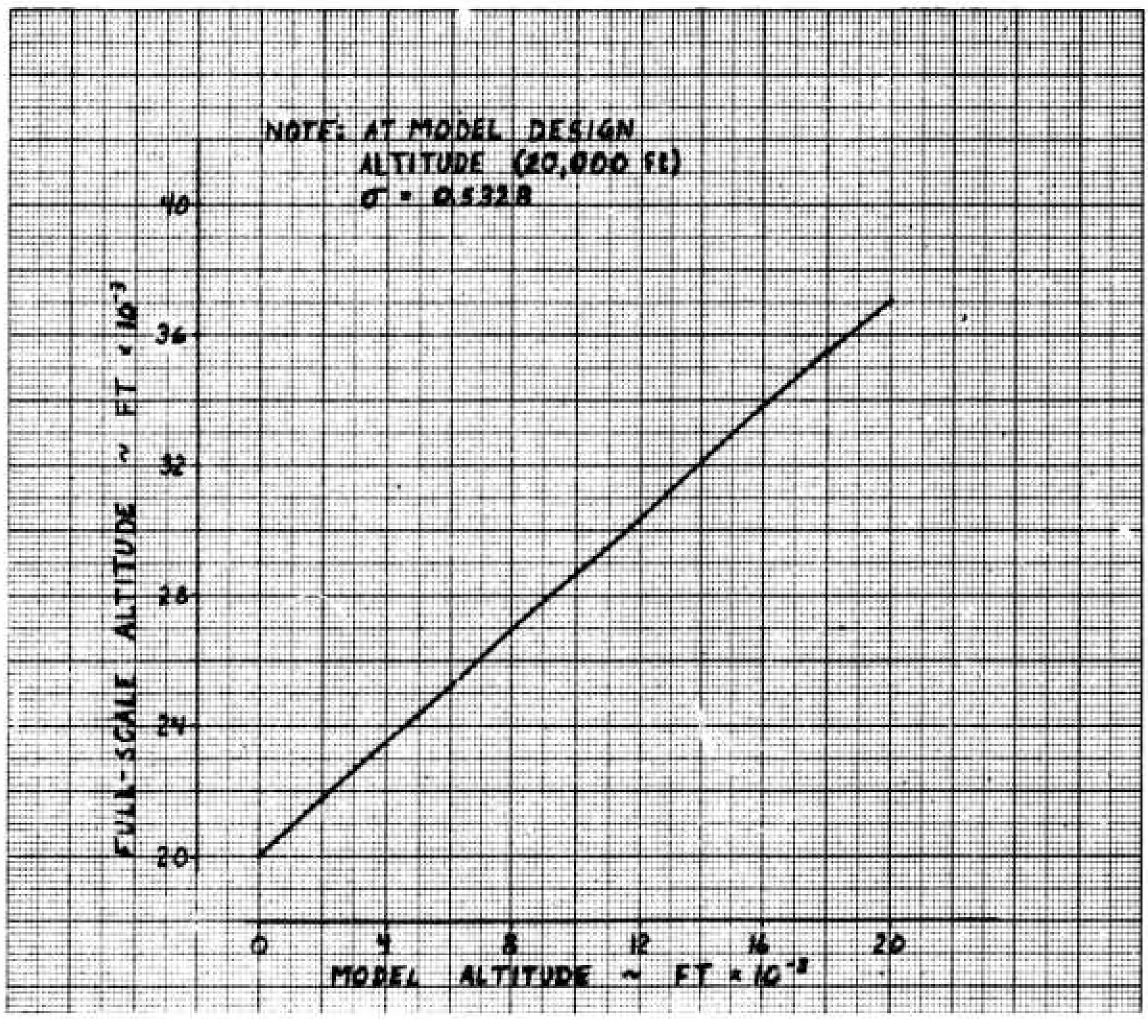


Figure 3 Relationship of Actual Model Altitude to Corresponding Full-Scale YF-16 Altitude

[1]Reference 1: Woodcock, Robert J., Some Notes on Free-Flight Model Scaling, AFFDL-TM-73-123-FCC, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, August 1973

Table 1

SCALE FACTORS FOR DYNAMIC FREE-FLIGHT MODELS

Linear Dimension	N
Mass (and Weight)	$N^3\sigma^{-1}$
Time	$N^{1/2}$
Linear Velocity	$N^{1/2}$
Linear Acceleration	1
Angular Dimension	1
Angular Velocity	$N^{-1/2}$
Angular Acceleration	N^{-1}
Dynamic Pressure	$N\sigma^{-1}$
Load Factor	$N^{-1}\sigma^{-1}$
Relative Density	1
Moment of Inertia	$N^5\sigma^{-1}$
Froude Number $\frac{V^2}{\ell g}$	1
Reynolds Number $\frac{V\ell}{\nu}$	$N^{1.5}\frac{\nu}{\nu_o}$

Where N = Model to Airplane Scale Ratio
(N = 0.3 for YF-16 Drop Model)
σ = Ratio of Local Air Density to that of Sea Level
(σ = 0.5328 for design altitude of 20,000 ft)
ν = Kinematic Viscosity
ν_o = Kinematic Viscosity at Sea Level, Standard Day
($\nu_o = 1.5665 \times 10^{-4}$ ft^2/sec)

Table 2

PHYSICAL CHARACTERISTICS OF THE YF-16 DROP MODEL

<u>Model General</u>	
Overall Length (excluding noseboom)	14.08 ft
Overall Span (without missiles)	8.67 ft
Design Gross Weight	937.5 lb
Design Center of Gravity (percent mean aerodynamic chord)	37.0 percent
Design Moments of Inertia	
I_{xx}	36.5 slug-ft^2
I_{yy}	216.8 slug-ft^2
I_{zz}	244.2 slug-ft^2
<u>Reference Dimensions</u>	
Length of Mean Aerodynamic Chord ($\bar{c}$)	39.37 in.
Span without Missiles (b)	104.40 in.
Wing Area (S)	25.20 ft^2

When delivered, the model was painted white except for small areas of the vertical stabilizer and the lower surfaces of the wings which were painted international orange to facilitate visual determination of the model attitude and flightpath. The paint scheme was changed before the third flight, but the change improved visibility only slightly.

It should be noted that the airframe of the Iron Bird was identical to those of the actual Drop Models; it was constructed in the same molds, of the same materials, and with the same attention to detail. Externally, there were only four differences. There was no nose boom, the nose was not hinged, there were no leading edge flaps, flaperons, or rudder, and the stabilators were ground adjustable and could be locked in any position within their normal range. Internally, the instrumentation, telemetry, and hydraulic flight control systems were omitted, but the Iron Bird was statically and dynamically balanced to exhibit the cg and inertia characteristics expected from the fully outfitted models. The complete parachute recovery system was retained.

Instrumentation:

The air data system (ADS) was manufactured specifically for this program by William F. Putman Co. of Princeton, New Jersey under contract to A&M. It consisted of a pitot boom which was mounted at approximately -5 degrees to the model x axis in the hinged nose section of the model, and associated tubing, sensors, heaters, and signal amplifiers which were mounted in the forward fuselage. The boom had two pitot-static tubes inclined at -10 degrees and -40 degrees to the boom axis. Each pitot-static tube was independently connected to its own set of static and differential pressure transducers[2]. The boom also supported an angle of attack vane with pivot axis normal to the model x axis (in the x-y plane), and an angle of sideslip (β) vane with pivot axis in the x-z plane at -135 degrees from the x axis (see figure 4). The pressure transducers were placed in a closed glass Dewar flask. This Dewar flask and the α and β signal amplifiers were wrapped in heater blankets and placed in a closed aluminum cylinder to minimize temperature effects. Stabilization of the temperature within the aluminum cylinder required 16 to 36 hours. It was then necessary to leave power on the heaters continuously between final calibration of these transducers and the actual model flight (a minimum of two days). A general procedure was to keep power on the ADS at all times.

To increase the accuracy of the altitude information, one of the static pressure transducers was calibrated to operate between 2000 feet and 14,000 feet mean sea level (MSL) and the other transducer was calibrated to operate between 10,000 feet and 20,000 feet MSL. Because of the arrangement of the static pressure ports on the pitot tubes, and the equipment used to calibrate these transducers, there was no way to insure that both transducers were sensing the same static pressures in the overlap region between 10,000 and 14,000 feet; in fact, data from flight 3-D-3 indicated that they were not. It was arbitrarily decided to display high altitude data in the cockpit above 11,000 feet, then

[2]National Semiconductor, Series LX 1600

switch to the low altitude data; this caused a discontinuity in the altitude information presented to the pilot which was mildly disconcerting. It also presented an obvious data analysis problem which was never satisfactorily resolved. There was also an altitude data resolution problem which may have increased the noisy altimeter indications described in this report. After conversion from the analogue output of the transducers, the least significant bit of the static pressure data words corresponded to 12 feet of altitude, but the output of the transducers was sufficiently unsteady to produce a scatter band of 36 to 96 feet. Apparently the resolution of the static pressure transducers was exceeded by the resolution of the data telemetry system.

Because of the uncontrolled nature of the first flight, the quality of the differential pressure data obtained from the ADS could not be determined. On the second flight, both differential pressure transducers provided inaccurate airspeed information. Postflight investigations revealed that one of the heater blankets around the Dewar flask may have failed, causing the transducers to become temperature dependent. It was also postulated that the cycling on and off of the heater blankets may have adversely affected the proper operation of the α and β signal amplifiers or that they too might have suffered some temperature effects.

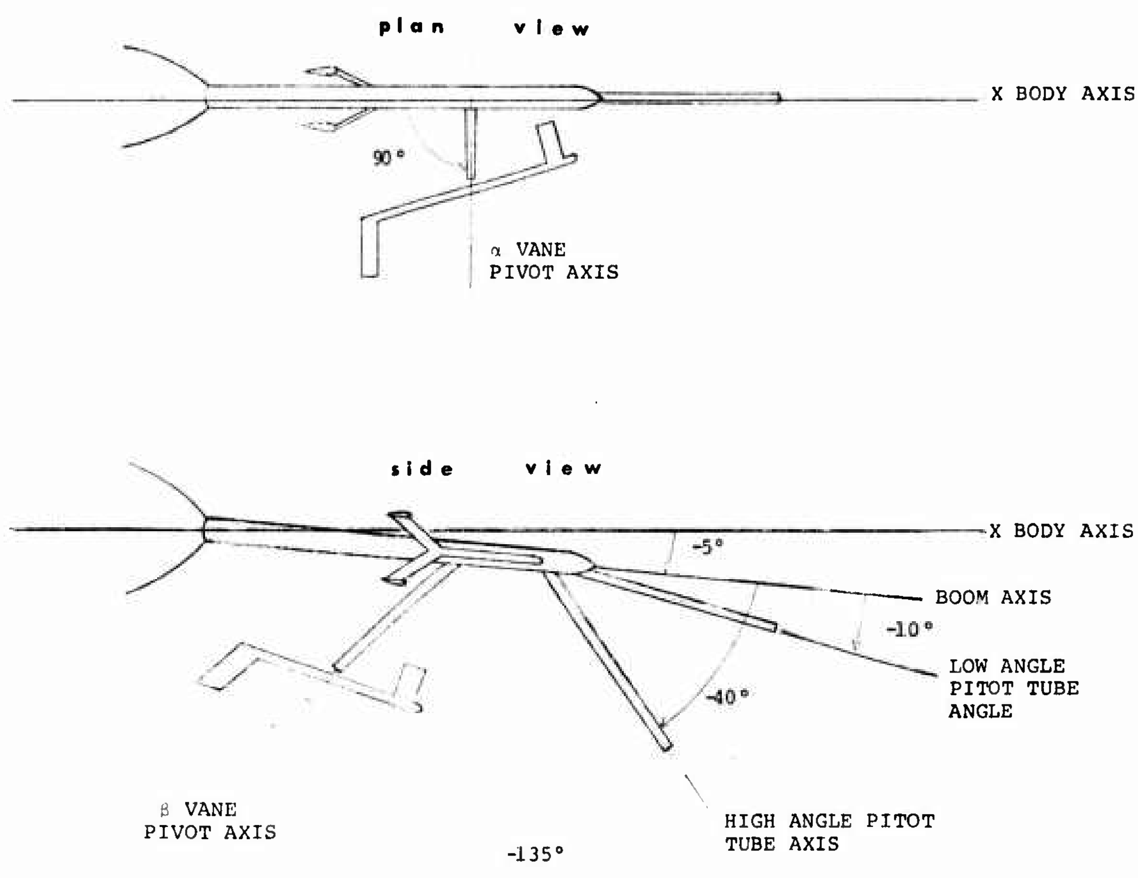


Figure 4 YF-16 Drop Model Nose Boom

The low angle of attack differential pressure transducer was replaced with a transducer[3] known to be temperature independent. The α and β signal amplifiers were eliminated, and required signal conditioning was performed without the signal amplifiers. The full 360-degree α and β ranges, or any portion thereof, could be selected prior to flight; however, the greater the range selected, the worse the resolution would be, and vice versa. For the third flight, an α range of -15 to +75 degrees and a β range of ± 20 degrees were selected. These modifications proved to be extremely beneficial and good airspeed and angle of attack data were acquired on the third flight. The angle of sideslip data appeared somewhat oscillatory and it was postulated that the airflow to the β vane was being disturbed by the high angle of attack pitot tube.

The attitude reference system chosen by A&M was a three-axis free gyro[4]. This gyro required 28-volt dc input and provided 360-degree attitude measurement in all three axes with a 0-to 5.0-volt output signal. It could be caged in all three axes by a discrete signal from the ground control station via the uplink telemetry system. This free gyro was selected because of the reduced probability of it tumbling during the anticipated violent post-stall and spin gyrations. Since there was no self-erecting mechanism, the gyro drifted in all three axes. Even when this drift remained within the one degree per five minutes tolerance, it caused operational problems which will be discussed later. Four of these gyros were purchased for the Drop Model project, and reliability was generally poor. Failures occurred repeatedly in the bearings, slip rings, gimbals, and caging mechanism. While the vendor would provide repairs under warranty, service was extremely slow and occasionally incomplete; several flight delays were caused by the unexpected failure of the only remaining operational attitude gyro. At the end of the program, one unit was declared unrepairable by the vendor. Both Atkins & Merrill and General Design were repeatedly asked to provide technical information, installation procedures, test porcedures, and handling requirements for these units, but none were ever received.

Prior to launch on the second flight, the gyro appeared to be caging and uncaging in response to momentary losses of the uplink telemetry signal (a steady uncage command was actually being transmitted from the ground control station). This situation was corrected prior to the third model flight by transmitting two discrete commands to the model and requiring that they both be present for three seconds before the gyro would cage and that they both be absent for one second before it would uncage.

A combination linear accelerometer/angular rate gyro unit[5] was selected for the Drop Model project. It contained three linear accelerometers to sense longitudinal accelerations of 0 to -2.5g, lateral accelerations of ± 1.5 g, and normal accelerations of -2.5 to +5.0 g, as well as three rate gyros to sense pitch and yaw rates of ± 200 degrees per second and roll rates of ± 400 degrees per second. Input power was 28 volts dc and the output signal was 0 to 5.0 volts. Four of these units were purchased for this project and all four appeared to be defective when delivered. The four units were returned to the vendor a

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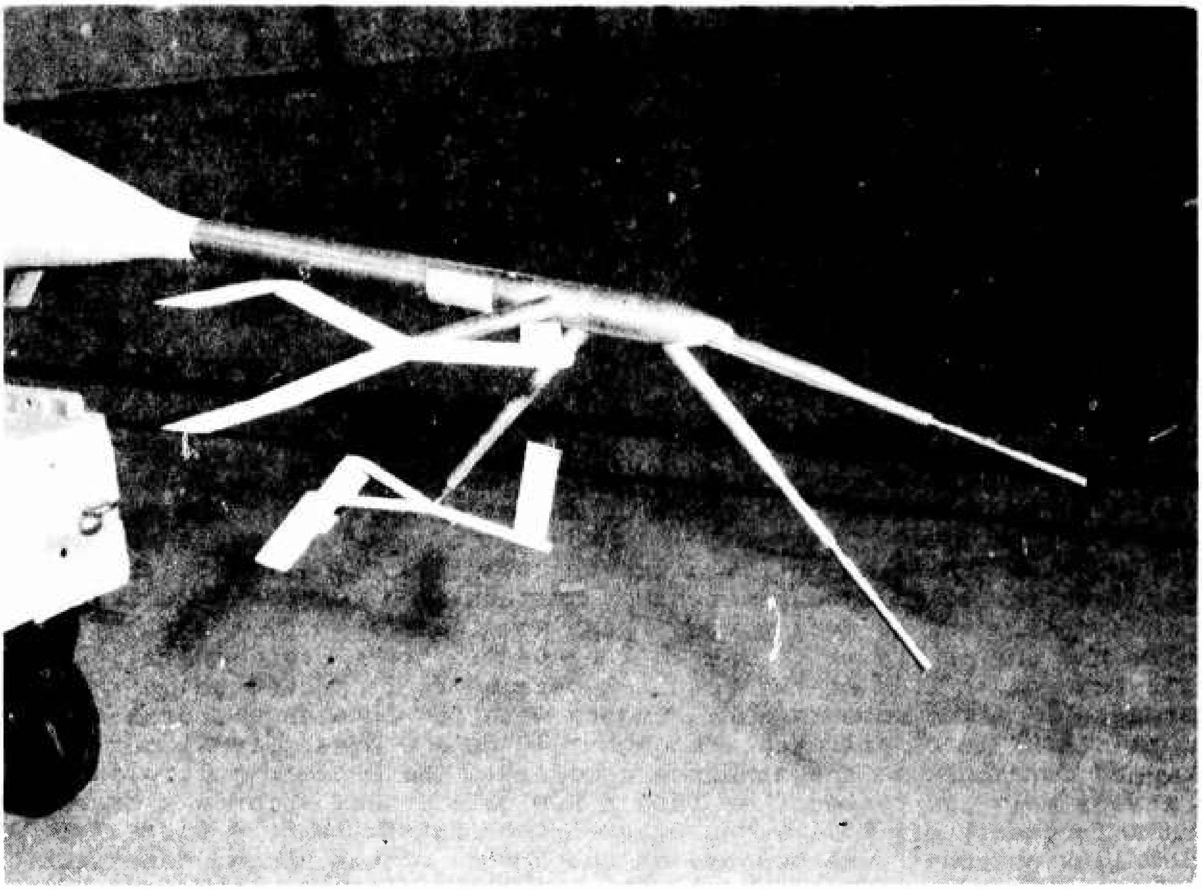
[3]Datametrics Barocel Pressure Sensor, Type 1300-2PSID

[4]Manufactured by General Design Inc., Model 6475

[5]Manufactured by Systron-Donner Corp., Model 7620-1



total of six times before it was discovered that the electrical connections were improperly labeled on the blueprints furnished by the vendor, and calibration efforts were apparently causing internal electrical failures. The electrical connectors were rewired and no further problems were encountered. Shortly before the third flight, it was determined that a longitudinal accelerometer range of ±0.5 g would be required to accurately determine the model chord force coefficient, but there was insufficient time to return even one unit to the vendor for rescaling.

An angular accelerometer unit[6] sensed pitch and yaw accelerations of ±10 radians/sec/sec and roll accelerations of ±30 radians/sec/sec. Input power was 28 volts dc and the output signal was 0 to 5.0 volts. Again, four units were obtained from the vendor. The internal heater circuits in three of these units were either inoperative or caused small step shifts in the output signals and were returned to the vendor for repair. The heater circuits were redesigned in two of these units.

A continuous rotary-motion potentiometer was mounted on each of the five model control surfaces to provide primary control surface position information. These were not a part of the onboard surface control loop. The linear variable differential transformer (LVDT) signals described below were a part of the onboard control loop. The output of each potentiometer and each LVDT was signal conditioned and telemetered to

[6]Manufactured by Systron-Donner Corp., Model 4591

the ground for comparison purposes. In addition, the uplink control surface command signals were also signal conditioned and telemetered back to the ground for postflight analysis.

Because the fiberglass model reflected very little radar energy, a C-band radar transponder was installed to permit accurate radar position and altitude data acquisition. This data was displayed in real time on a radar position plotting board, and a closed circuit television picture of the plotting board was presented in the ground control station and the data acquisition center. (A ground-based, radar-aimed television picture of the model in flight was also presented at both locations).

Telemetry:

The pulse code modulated (PCM) downlink telemetry system was designed to transmit the data required by the model pilot and the ground based computer for real time control of model, as well as those parameters required for postflight analysis of the model's flying characteristics. The downlink frame consisted of two synchronization words, three data words which monitored thirty discrete on/off functions, two subcommutated words which cycled through eight parameters each (yielding 20 samples per second), and 33 data words. Each word consisted of ten information bits and one parity bit. The entire 40-word frame was sampled 160 times per second. A list of the downlink parameters is presented in table 3. Signals from the onboard data sensors were fed into an airborne interface unit[7] (AIU) to be filtered (through a 40 Hz low pass filter) and conditioned for input to the airborne encoder[8]. The encoder multiplexed the data signals and formed them into a PCM data stream which was transmitted on a frequency of 1511.5 MH_z by an L-band tansmitter[9]. A blade-type downlink antenna[10] was mounted on the bottom of the hinged nose section of the model. A three-inch diameter aluminum cylinder, ten inches long, within the nose section served as the required antenna ground plane.

The uplink, or command, telemetry stream was a 13-word frame, which also cycled at 160 frames per second. Each data word carried ten data bits plus three "comparison bits" which were the inverse of the three most significant data bits in that word. The uplink frame consisted of two synchronization words, five surface command words (one for each flight control surface), three 10-bit discrete words for systems control, and three spare words. A list of uplink parameters is presented in table 4. The command telemetry signals were received on a frequency of 1712.0 MHz by the airborne receiver[11], demultiplexed by the decoder[12],

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[7]Designed and built by Atkins & Merrill for the Drop Model Project

[8]Manufactured by IED division of Conic Corp, Model PCM-410-2

[9]Manufactured by Conic division of Conic Corp, Model CTM-UHF-525LM

[10]Manufactured by Watkins-Johnson Co, Type KLE-U-2A

[11]Manufactured by Babcock Electronics Corp, Model BCR-101C

[12]Manufactured by Aacom, Inc., Type 15

Table 3

YF-16 DROP MODEL DOWNLINK TELEMETRY PARAMETERS

Word	Parameter
1	Discrete Word #1
2	Discrete Word #2
3	Discrete Word #3
4	Commutated Ch #1
5	Commutated Ch #2
6	Rudder LVDT
7	Rt Flaperon LVDT
8	Rt Flaperon LVDT
9	Rt Stabilator LVDT
10	Lt Stabilator LVDT
11	Rudder Cmd
12	Rt Flaperon Cmd
13	Lt Flaperon Cmd
14	Rt Stabilator Cmd
15	Lt Stabilator Cmd
16	Rudder Pos
17	Rt Flaperon Pos
18	Lt Flaperon Pos
19	Rt Stabilator Pos
20	Lt Stabilator Pos
21	Hi Ang Diff Press
22	Lo Ang Diff Press
23	Hi Ang Stat Press
24	Lo Ang Stat Press
25	Yaw Accel
26	Pitch Accel
27	Roll Accel
28	Long Accel
29	Yaw Angle
30	Pitch Angle
31	Roll Angle
32	Angle of Sideslip
33	Lat Accel
34	Yaw Rate
35	Pitch Rate
36	Roll Rate
37	Norm Accel
38	Angle of Attack
39	Synchronization
40	Synchronization

Bit	Discrete Word #1
1	Spare
2	Spare
3	Spare
4	Spare
5	Spare
6	Spare
7	q_c > 215 psf
8	Arm Cmd
9	Drogue Cmd
10	Main Chute Cmd

Bit	Discrete Word #2
1	Drogue Gun Fired
2	Drogue Riser Rel #1
3	Drogue Riser Rel #2
4	Int Riser Rel #1
5	Int Riser Rel #2
6	Main Riser Rel Fwd
7	Main Riser Rel Aft
8	Spare
9	Spare
10	Spare

Bit	Discrete Word #3
1	Gyro Caged
2	Loss of DownLink
3	Hyd On
4	Loss of Uplink Sync
5	Loss of Uplink Signal
6	Command Enable
7	Alt < 6,000 ft
8	Loss of Pri or Aux Bat Volt
9	Model Released
10	3 Sec Delay

Word	Commutated Ch #1
1	Spare
2	+15VDC
3	-15VDC
4	+5VDC
5	28VDC Main
6	28VDC Aux
7	28VDC Hyd
8	Hyd Pressure

Word	Commutated Ch #2
1	0VDC Cal
2	2.5VDC Cal
3	5VDC Cal
4	0VDC Cal
5	5VDC Cal
6	Hyd Temp
7	Spare
8	Spare

Table 4

YF-16 DROP MODEL COMMAND TELEMETRY PARAMETERS

Word	Parameter
0	Synchronization
1	Synchronization
2	Rudder Cmd
3	Rt Flaperon Cmd
4	Lt Flaperon Cmd
5	Spare
6	Spare
7	Rt Stabilator Cmd
8	Lt Stabilator Cmd
9	Spare
10	Discrete Word #1
11	Discrete Word #2
12	Discrete Word #3

Bit	Discrete Word #1
0	Spare
1	Spare
2	Spare
3	Spare
4	Spare
5	Spare
6	Hydraulics On
7	Parachute Arm Cmd
8	Drogue Deploy Cmd
9	Main Deploy Cmd

Bit	Discrete Word #2
0	Gyro Cage Cmd #1
1	Loss of Downlink Sync
2	Spare
3	Spare
4	Spare
5	Spare
6	Spare
7	Gyro Cage Cmd #2
8	Spare
9	Spare

Bit	Discrete Word #3
0	Spare
1	Spare
2	Spare
3	Spare
4	Spare
5	Spare
6	Spare
7	Parachute Arm Cmd
8	Drogue Deploy Cmd
9	Main Deploy Cmd

signal conditioned at the AIU, and sent to the appropriate relay or actuator. A blade-type uplink antenna[13] (similar to the downlink antenna) was mounted on the same ground plane just aft of the downlink antenna.

Hydraulic Flight Control System:

The hydraulic flight control system consisted of a motor/pump assembly[14], two reservoirs, a manifold, a six-channel servocontroller, and five electrohydraulic servoactuators[15]. The motor/pump assembly operated on 28 volts dc and delivered 2.0 gallons per minute at 1500 psig. The servocontroller received a control surface command signal from the telemetry uplink and compared it with a surface position signal produced by a linear variable differential transformer (LVDT) at the control surface. A difference between the surface command signal and the LVDT position signal caused the appropriate servovalve to open in the acturator and reposition the surface. When the command signal equalled the LVDT position signal, the servovalve closed and the control surface remained at its newly commanded position. While LVDT sensed surface positions were telemetered to the ground, a separate potentiometer was used as the primary control surface position sensor for data analysis and real time model control.

[13] Manufactured by Watkins-Johnson Co, Type QSE-U-2A

[14] Second stage auxiliary power supply from the Minuteman Missile modified by Ogden Air Logistics Center, Hill AFB, Utah (GFE)

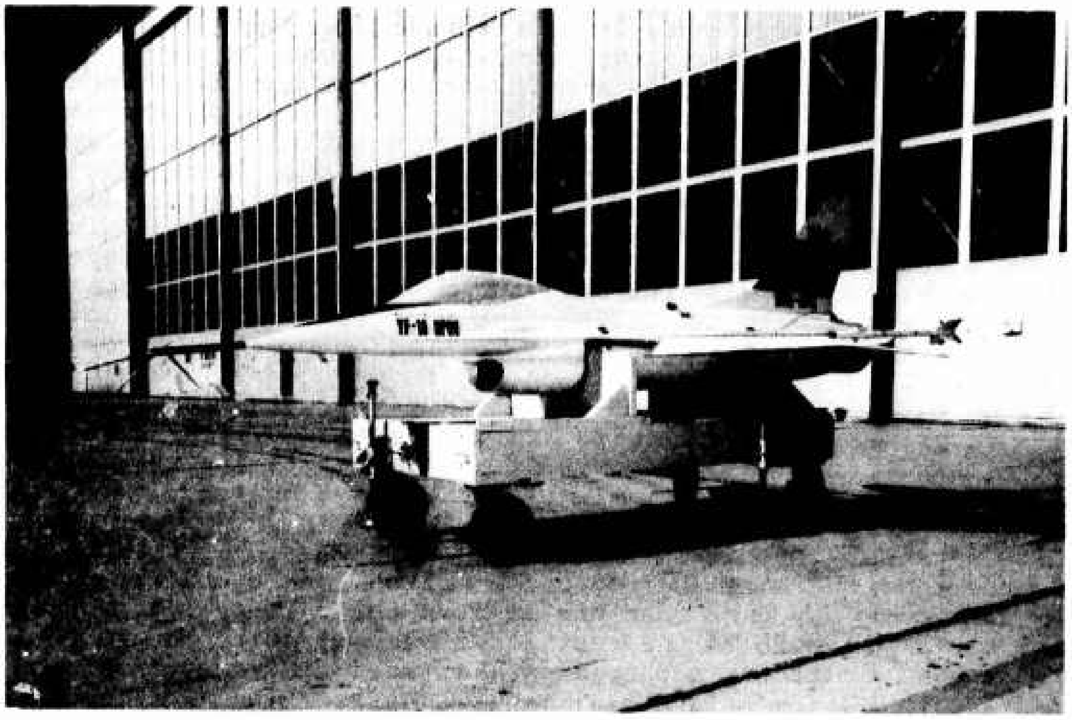
[15] The servocontroller and servoactuators were manufactured by Bertea Corporation, Type 239900 and Type 240100P, respectively

Parachute Recovery System:

The parachute recovery system was designed to bring the model to a safe landing in an upright, level attitude at a moderate descent rate if it settled on relatively level terrain. It consisted of a pilot parachute, a drogue parachute, a main parachute, and the electronic and pyrotechnic devices required to deploy the parachutes in the proper sequence. This sequence was controlled by the electronic relays, timers, and logic elements in the parachute logic box (PLB) which integrated signals from onboard sensors or the uplink telemetry system (as described below) and provided signals to fire the appropriate pyrotechnic devices. This was actually a completely redundant system with two independent logic systems (in the same PLB) providing signals through separate pyrotechnic circuits to two independent pyrotechnic devices, either of which was sufficient to initiate the desired step in the recovery sequence. Each system fired its pyrotechnic device independently, regardless of whether or not the other system had already initiated that particular step. The primary logic circuits and pyrotechnic devices were powered from the main electrical power system and the auxiliary system was powered from the parachute auxiliary battery.

The necessary conditions for arming of the recovery sequence were a disconnect of the model/helicopter umbilical cable and the removal of either of two safety pins (one pin enabled the primary logic circuits and the other pin enabled the auxiliary logic circuits in the PLB). Both of these conditions occurred as the model fell away from the launch-rack mechanism on a normal launch, or as the model, launch rack, and tow cable separated from the helicopter in an emergency jettison. Once the system had been armed, the recovery sequence could be initiated automatically from onboard the model by: (1) a drop in either primary or auxiliary battery voltage below 21 volts, (2) continuous loss of telemetry signal or synchronization for more than 10 seconds, (3) actuation of a barometric switch which closed if the model descended below 6000 feet pressure altitude, or (4) actuation of a "q_c" switch which closed if the model differential pressure exceeded 215 pounds per square foot (psf) (approximately 247 knots). The "q_c" switch commanded only pilot and drogue parachute deployment, and did not command main parachute deployment. Prior to the first flight, these automatic features were inhibited when manual deployment was attempted from the ground control station via the uplink telemetry system. After the first flight, these automatic deployments could not be inhibited from the ground control station in any manner. Deployment of the drogue parachute could be manually commanded from the ground control station any time after a normal launch or an emergency jettison. Deployment of the main parachute could be manually commanded from the ground control station any time after a drogue parachute deployment command had been sent by the PLB.

Parachute deployment began with the firing of the drogue deployment pyrotechnic device. A drogue slug, weighing approximately 4.5 pounds, was ballistically fired out of the aft end of the "engine bay". This drogue slug carried the pilot parachute out into the airstream where it inflated and pulled out the 8-foot drogue parachute. The drogue parachute was scaled to the full-scale YF-16 spin recovery parachute, and it stabilized the model in a nosedown, 150-foot per second (fps) descent. Ten seconds later, the drogue parachute risers were pyrotechnically released from the model structure and the drogue parachute then extracted the 67-foot main parachute. The main parachute slowed the model descent rate to approximately 15 fps, still in a nosedown attitude.



Ten seconds after main parachute deployment, the model repositioned to the horizontal attitude when the intermediate parachute riser connections were pyrotechnically released from the aft model structure. After another 15 seconds had elapsed, the nose latch was released and the nose swung to the up position and the hydraulic pump was turned off. Touchdown occurred on the air intake with a 15 fps descent rate. The left parachute risers were released at touchdown allowing the parachute to collapse.

Electrical System:

All electrical power for the model was provided by nickel cadmium batteries. The main electrical system provided power for all electrical and electronic components except the hydraulic motor/pump assembly and the auxiliary parachute deployment system. The instrumentation regulated power supplies, the telemetry components, the C-band radar transponder, the electrohydraulic servoactuators, the servocontroller, the AIU, and the primary parachute deployment system all derived power from the main electrical system. During free flight, the main system was powered by a 28.8-volt, 5.5-ampere-hour battery capable of providing model power for approximately 15 minutes. During tow, the main system could be powered from the helicopter through the umbilical cable by the 30.0-volt alternate battery. It was originally intended to use the 28-volt dc helicopter electrical system to power the model during tow, but it was determined that there was a 2-volt loss in the umbilical cable and the telemetry system became very noisy when operated on 26-volt helicopter power. The 30.0-volt alternate battery solved that problem by delivering approximately 28-volts to the model. Switch over from the alternate

battery to the main battery and activation of the hydraulic system was normally commanded from the model monitor/launch box onboard the helicopter or occurred automatically when the umbilical cable separated. The model hydraulic motor/pump assembly derived its operating power from a separate 28.8-volt, 42.0-ampere hour hydraulic battery. The 28.8-volt, 2.0-ampere hour parachute auxiliary battery provided power for the auxiliary parachute logic circuits and pyrotechnic devices. Its sole function was to provide a redundant power source to fire the parachute deployment system in case the main power source failed. If either the main battery voltage or the parachute auxiliary battery dropped below 21 volts, the automatic parachute deployment sequence would be initiated.

THE GROUND CONTROL STATION

The ground control station consisted of the uplink and downlink telemetry systems, the cockpit, the flight control computer, and the equipment necessary to interface these components. The computer program (software) for the flight control computer was also considered part of the ground control station system. All ground control station components were located in a semimobile trailer. Only 110-volt, 60-cycle ac electrical power was required for system operation, but the externally mounted air-conditioning unit required 220-volt, 3-phase power.

Telemetry:

The telemetry system consisted of a receiver[16] and a PCM decommutator (decoder)[17] which fed downlink telemetry information through the interface equipment directly into the proper computer memory locations, an uplink encoder[18] which accessed information directly from computer memory locations, a transmitter[19], and an automatic tracking system[20] which drove the receiver/transmitter antenna in azimuth only (360 degrees). The antenna tracking system could be manually operated in azimuth or in elevation (0 to +90 degrees). The antenna was mounted on top of the ground control station trailer.

Interface System:

The interface system was built especially for the Drop Model program by Atkins & Merrill, Inc. It performed the dual functions of controlling computer operations and transferring information between the computer, the cockpit, and the telemetry system. It performed digital-to-analogue conversions for operation of the cockpit flight instruments and analogue-to-digital conversions on the pilot's stick and rudder commands for

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[16]Manufactured by Microdyne Corp., Model 1100-AR

[17]Manufactured by Aydin Monitor Co., Model 1023A

[18]The uplink encoder was an integral part of the input/output interface system designed and built by Atkins & Merrill

[19]Manufactured by Conic Division of Conic Corp., Model CTM-UHF-525LM

[20]Manufactured by Aacom, Inc., Model AS-55000

input to the computer. It also provided timing, synchronization, and multiplexing of the uplink telemetry data. Since this system was the central channel through which the flow and manipulation of all data was controlled, the importance of the proper operation of this system cannot be overemphasized.

At the time that the ground control station was delivered to Edwards AFB, development work was still being performed on the interface system by the contractor. Progress was slow and some of the difficulties which eventually contributed to the termination of the project were evident even then. As described below, it was difficult to determine whether problems were caused by interface system design deficiencies, hardware failures, or programming errors. Again, the contractor's documentation was incomplete and inaccurate.

When AFFTC took over the project in June 1975, reliable operation of the ground control station had not been demonstrated. The system was still subject to random failures. Integrated circuits (IC) failed frequently, the computer memory locations in which the program was stored were being altered for no discernible reason, and output signals to the cockpit instruments and indicator lights were extremely noisy. Some of these difficulties were eventually bypassed (but not corrected) by clever computer programming. The integrity of the IC sockets, solder joints, and the construction of the printed circuit boards throughout the interface unit became suspect. Many boards became warped because the connectors and guide rails were misaligned. Each time a board was removed to check out a circuit or replace a failed component, it was further weakened. These problems were aggravated by temperature fluctuations which occurred within the ground control station when the air-conditioning system was turned off each night and weekend. Several of the most critical and least reliable printed circuit boards were remanufactured and the reliability of the system was somewhat improved.

Postflight analysis of the data from the second and third model flights revealed that spikes of extremely short duration (one or two PCM frames, 12.5 milliseconds) were present in the uplink control surface commands. It was observed throughout the program that the interface system altered the data stored in computer memory locations for the uplink commands and that it transferred data incorrectly at random intervals when there were no obvious failure indications. This was believed to be the primary source of the control surface spikes and the noise in the cockpit indicators. No provision was made to record the operations of the ground control station components to permit detailed analysis of the operation and interaction of the uplink and downlink telemetry systems, the cockpit displays and controls, the interface system, and the computer. Installation of a suitable tape recorder would enable recording of these operations to facilitate maintenance and troubleshooting and to provide a backup for the recording at the central AFFTC data acquisition facility during model flights.

It was requested that a computer design engineer be assigned to perform a complete critical evaluation of the ground control station interface system. After becoming familiar with the purpose and operation of the system, he was to determine the adequacy of the original design and the layout and fabrication of the existing equipment. He was to supervise the remanufacture of those components he found to be deficient and, if necessary, he was to redesign the entire system and supervise the manufacture or acquisition of the redesigned system. He was also expected to correct and complete the available documentation and establish

maintenance and operational procedures for the system operators and technicians. It was estimated that this would take approximately six months, and the manpower and resources were not available to the Drop Model Project. This course of action is still considered essential to the reliable operation of the ground control station and the efficient conduct of the project.

Flight Control Computer and Software:

Atkins & Merrill provided a Datacraft 6024/5 minicomputer, capable of storing 8192 24-bit words and performing approximately 500,000 separate operations per second, to perform the necessary flight control system computations. Peripheral computer equipment included a teletypewriter, a paper tape punch/reader, a line printer, and a direct memory access console (DMAC). After the ground control station was transported to Edwards AFB, the computer program was written in assembly language at the Atkins & Merrill Tulsa, Oklahoma facility. The program was brought to Edwards on paper tape (in machine language) without having been debugged and loaded into the computer memory. The program included several rate damping flight control modes, an automatic spin recovery mode, a complete full-scale YF-16 flight control system mode, the capability to select up to nine preprogrammed maneuver sequences, and it included a very limited flight simulation of the model (suitable only for procedure training and not engineering analysis). Because the computer memory was limited, operation in assembly language was not possible and debugging was attempted in machine language through the DMAC. However, the program was so complicated and the failures in the interface unit were so frequent that contractor personnel were unable to determine whether specific problems were caused by programming errors or interface system malfunctions. Progress diminished considerably and shortly thereafter Atkins & Merrill was released from the project.

When the AFFTC accepted responsibility for Drop Model systems development, a simulation engineer was assigned part time to study and modify the program so that only pitch rate and angle of attack feedback loops were retained in the pitch axis and roll rate and yaw rate feedback loops were programmed in the roll and yaw axes. Downlink data scaling and storage, cockpit instrument drive, and discrete bit processing were programmed. Entry into the nonessential modes of operation described above was prohibited because it was too time consuming to debug those portions of the program. The simplified program was then debugged in machine language using the DMAC. This was all accomplished in parallel with other efforts to improve the reliability of the interface system and to develop and check out the model systems, particularly their interaction with, and response to, the ground control station.

An assembly language compiler and an additional 8192 words of computer memory were purchased to permit computer programming through the teletypewriter in assembly language. However, the time required to reprogram and document even the simplified flight control system was extensive and the time available to the programmer/engineer was not sufficient. Hence, standard practice was to accomplish all program modifications in machine language through the DMAC, a very slow and cumbersome process.

Before the first model flight, the simplified flight control system was expanded to allow selection of four different rate feedback gains in each of the three axes; one of these gains in each axis was variable, set by potentiometers on the test engineer's panel. The other capabilities originally envisioned for the ground control station were to be added as

the project progressed and requirements dictated, however, the project was terminated before the other function could be implemented.

Cockpit:

The cockpit included a pilot's station and a test engineer's station. The pilot was presented attitude and heading information on a standard three-axis attitude director indicator (ADI), airspeed, altitude, and rate of climb on aircraft type indicators, and angle of attack, angle of sideslip, yaw rate, and control surface positions on various indicators and meters. The pilot's altimeter was a standard aircraft instrument modified by Atkins & Merrill so that it was electrically driven by computer-generated sine and cosine signals. Altitude indications were erratic, due partly to the scatter in the static pressure telemetry data discussed earlier and partly to noise generated by the interface unit in the ground control station. The altimeter was unable to respond to the high descent rates encountered shortly after launch and the system was prone to display errors of 1000 feet. After much of the noise was eliminated from all the cockpit instruments, the original altimeter was temporarily replaced with a dc servomotor indicator of the type used in most modern simulators. Both the 1000-foot errors and the lag were eliminated; the contractor-supplied indicator should be replaced by a dc servomotor altimeter.

The pilot made control inputs through a conventional center stick and rudder system which employed springs for control centering and artificial feel. A large deadband was found about the center position of the stick and rudders in all three axes. A sidestick controller, similar to the one used in the full-scale YF-16, was also provided but was not made operational during the project. The pilot's stick and rudder inputs were passed through an analog-to-digital converter in the interface system and stored directly in the computer memory 160 times each second for subsequent integration into the overall flight control system calculations of model control surface commands.

At the flight test engineer's station was a panel from which various modes of operation of the flight control system computer could be selected (see figure 5). These modes included rate feedback in all three axes, angle of attack hold and pitch angle hold in the pitch axis, bank angle hold in the roll axis, and angle of sideslip and heading angle hold in the yaw axis. Also, the complete flight control system of the full-scale YF-16 aircraft could be selected or any one of nine preprogrammed, computer generated maneuver sequences could be initiated. A simulation capability was programmed into the ground control computer, and that, too, was controlled from the test engineer's station. As described above, the program was modified so that entry into only the angle of attack feedback and rate feedback modes was permitted; the nonessential modes were not debugged, and entry into those portions of the computer program were eliminated in the program itself.

Both the pilot and the test engineer had access to the manual parachute deployment command buttons, recovery system status indicator lights, telemetry system status indicator lights, UHF radio and interphone communications, and television monitors showing ground-based television pictures of the model in flight and the radar position plotting board.

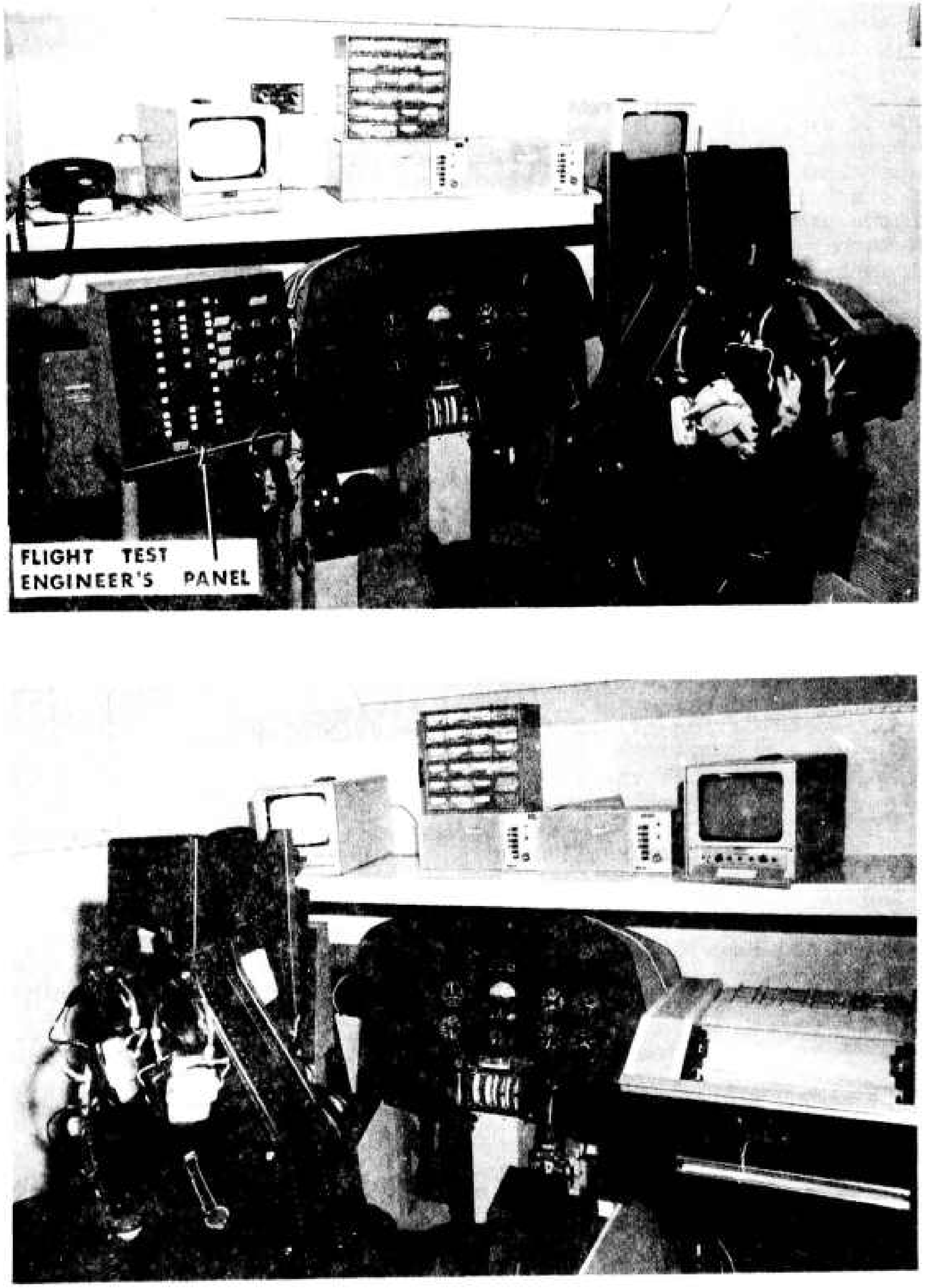


Figure 5 - YF-16 Drop Model Ground Control Station
Cockpit and Flight Test Engineer's Panel

UH-1N Selection:

The UH-1N helicopter was chosen over the other launch vehicles available for several reasons. It had demonstrated the capability to attain 22,000 feet pressure altitude (with minimum crew and no payload) during its initial operational flight tests; at the time, no other helicopter possessed this altitude capability. Selection of a DC-130 or NB-52 aircraft would have required expensive launch pylon modifications and extensive launch aircraft/model compatibility and separation tests. It was expected that the Drop Model would generate lift equal to about half its weight, and thus the helicopter would be able to attain an altitude of 18,500 feet with the model in tow. A waiver was obtained from Warner-Robbins Air Logistics Center for the duration of the test program to operate the UH-1N helicopter up to 18,500 feet provided all helicopter systems operated normally. The Iron Bird tests revealed that it was necessary to tow the model at approximately -10 degrees angle of attack (with the model cg at 35 percent MAC), and the resultant negative lift decreased the maximum altitude to approximately 17,000 feet.

Class II Modifications:

Class II modifications[21] to the UH-1N helicopter to enable it to perform the tow/launch mission consisted of:

1. Installation of the supplementary oxygen system.

2. Installation of the model monitor/launch box (MLB) and the upper umbilical cable.

3. Tiedown of the alternate battery.

4. Installation of the launch rack retrieval winch.

5. Attachment of the safety pin removal line.

The steel tow cable and the lower umbilical cable were attached to the helicopter cargo hook and were not considered to be modifications.

Regulations required that all occupants aboard Air Force aircraft use supplemental oxygen on flights in which the cabin altitude exceeds 10,000 feet. Since the UH-1N had no installed oxygen system, several different supplementary oxygen systems were provided during the course of the program to meet this requirement. In all cases, sufficient oxygen was placed aboard to sustain four crewmembers for 60 minutes at 20,000 feet.

The model monitor/launch box provided the following indications of an unsafe condition in the model parachute deployment system prior to launch:

[21]These modifications were authorized by class II modification packages M-4-A-002Z.

1. An amber caution light illuminated if either of the two safety pins were removed.

2. A second amber light lit up if any relay in either the primary or the auxiliary parachute logic circuits was not in the "safe" position.

3. A third amber light illuminated if the model logic indicated that the umbilical cable was disconnected. (This light only indicated an unsafe condition in the model logic. If the umbilical cable actually did separate, all three amber lights and the red light would illuminate because all "safe" signals would be lost. However, deployment of the parachutes would still be inhibited unless the safety pins were also removed.)

4. Simultaneous illumination of all three amber lights also illuminated a red warning light to indicate that the parachute system was armed and deployment could occur at any time.

The MLB also provided the capability to control the following model systems prior to launch:

1. When helicopter power was selected, the model main electrical system was powered from the alternate battery aboard the helicopter and the hydraulic system was switched off; when model power was selected, power for the main electrical system came from the main battery aboard the model and the hydraulic system was switched on.

2. When control enable was selected, the hydraulic system was switched on and the model control surfaces responded to uplink telemetry commands to verify continuity of the ground control station-to-model command path; when control enable was not selected, the hydraulic system was off and control surface commands were inhibited by the airborne interface unit (AIU).

3. When manual nose lift was selected, the nose latch was released and the nose swung to the up position to facilitate return of the model to its dolly after a captive flight or an aborted mission.

4. When launch was selected, the hooks on the launch-rack mechanism were opened releasing the model, and the warning functions on the MLB were deactivated. (When the umbilical cable separated, relays aboard the model automatically switched on the hydraulic system and the main electrical system, logic circuits enabled control surface response to telemetry commands, and armed the parachute recovery system if the safety pins were also pulled.)

5. The MLB also selectively indicated voltages of the four electrical power sources for the model: the main battery, the auxiliary parachute battery, the hydraulic battery, and the alternate battery aboard the helicopter.

The MLB was positioned inside the helicopter cargo/passenger compartment. The launch box operator (LBO) was a member of the Drop Model test team who was intimately familiar with the model, particularly the parachute recovery system. He continually monitored the MLB throughout the tow portion of the flight. Specific emergency procedures in response to unsafe indications on the MLB or failures or anomalies are presented in Appendix A, checklist 10.

The upper umbilical cable ran from the MLB in the helicopter cargo/passenger compartment, out the cargo door, and around the bottom of the fuselage where it was clamped to the helicopter within 12 inches of the cargo hook. It was connected to the lower umbilical cable at that point by a quick release plug. The umbilical cable carried the parachute system monitoring circuits and the model systems control circuits described above, and power from the alternate battery (onboard the helicopter) to power the model main electrical system prior to launch. The alternate battery was strapped to the cargo tiedown fittings on the floor of the helicopter cargo compartment.

The launch rack retrieval winch was used to hoist the launch rack into the helicopter after the model was launched. The winch was attached to cargo tiedown fittings on the floor of the helicopter cargo compartment near the door. A 550-pound test parachute cord was used as the retrieval line; a 150-pound controlled break point was placed in the line at the winch to reduce the probability of the line snapping back and getting fouled in the helicopter rotors during an emergency jettison. Approximately two feet of the 150-pound line was wound around the winch drum, then a 50-pound controlled break point was provided to enable the launch-rack mechanism and tow cable to break the retrieval line if jettison occurred after the model was launched. A 30-pound test line was attached between the 550-pound retrieval line and the winch platform to prevent wind loads from unwinding the line from the winch.

With the system described above, the parchute system safety pins would be removed only if the model separated from the launch-rack mechanism. Since this would not occur if the model was jettisoned, parachute deployment would be inhibited and the model would be destroyed. Prior to the second model flight, a safety pin removal line was added to the system. This line was attached to a cargo tiedown ring inside the helicopter and followed the umbilical cable down to the model where it was connected to both safety pins. If the model was jettisoned, this line would pull the safety pins, then break at the tiedown ring. The parachutes could then be deployed either by telemetry signal or by the internal, automatic deployment sensors.

Installation and checkout procedures for the helicopter systems can be found in Appendix A, checklists 8 and 9.

GROUND PREPARATIONS

SIMULATION

A restricted[22] six-degree-of-freedom, fixed-base, analogue simulation of the Drop Model was developed to support the flight test program. The cockpit and test engineer's panel duplicated those in the ground control station and a hydraulic force feel system provided and accurate representation of the control stick and rudder pedal characteristics of the ground control station.

Because model flight time was extremely limited, it was necessary to perform only those maneuvers which would yield the greatest amount of the most useful data in the least amount of time. The Drop Model simulation was used by project test engineers to develop a very detailed flight plan for each flight which would result in the most efficient use of the flight time available. The simulator was also used to determine a no-wind launch point and expected ground track which would bring the model to the planned parachute deployment position. The model pilot spent many hours in intensive training sessions learning the flight planned maneuver sequence and the expected model responses.

The simulation was initially generated using performance and stability and control derivatives calculated from full-scale YF-16 flight tests. These derivatives were to be modified as Drop Model flight test data became available. After the last Drop Model flight, changes were made in the simulator lift, drag, and pitching moment coefficients which more closely reflected the flight-derived coefficients.

PRELIMINARY GROUND TESTS

In addition to performing development work on the ground control station and calibrating the model instrumentation, the Drop Model test team conducted simulator studies and ground tests in preparation for the first captive flight on model 002. Those efforts are described below.

Feedback Gain Determination:

When it was decided to reprogram the flight control computer with a simple rate feedback flight control system, the Drop Model simulation was used to determine the optimum feedback loop gains. Since the model was expected to be longitudinally unstable with the cg at 35 percent mean aerodynamic chord (MAC), most of the effort was directed toward providing artificial stability. It quickly became apparent that, while pitch rate feedback alone would make the airplane flyable, it did not yield acceptable handling qualities to enable the pilot to perform

[22]The simulation was restricted in that the equations of motion used in the simulation were derived assuming an ideally flat, nonrotating earth. For the airspeeds, altitudes, and distances under consideration, this assumption introduced only negligible errors. In addition, the lateral acceleration term was omitted from the formulation of the total acceleration term. Since this term was very small compared to the longitudinal and normal acceleration terms, this assumption also introduced negligible errors.

precise flight test maneuvers. To assist in maintaining a desired angle of attack (within the required ±1 degree), an angle of attack feedback loop was also incorporated into the pitch axis control laws. This combination yielded acceptable pitch characteristics. While the model was stable in the roll and yaw axes, it was so responsive (because of its small size) that rate feedback in these axes was necessary for precise roll and heading control; overall handling qualities were also improved.

The pitch axis gains were determined independently of the roll and yaw axis gains. The project engineer systematically tried various combinations of gains until the simulator response offered the most desirable combination of stability and responsiveness. His decisions were based upon past experience as a flight test engineer and a fighter pilot. Both project test pilots then flew the simulator and concurred with the engineer's optimum gain selections. As mentioned earlier, the rate feedback gains in each axis could be changed at any time from the test engineer's panel. Those gains which could be selected are presented in table 5 and the optimum gains are noted; at no time during any model flight was a nonoptimum gain selected.

Table 5

CONTROL SYSTEM FEEDBACK GAINS[a]

	Pitch Rate Feedback Gain, Kq (deg/deg/sec)	Roll Rate Feedback Gain, Kp (deg/deg/sec)	Yaw Rate Feedback Gain, Kr (deg/deg/deg)
MIN SAS	0.3	0.0	0.0
Rate Damp 1	0.4	0.06	0.015
Rate Damp 2	0.6[b]	0.18[b]	0.045[b]
Rate Damp 3 (Variable)	0.3 - 1.3	0.0 - 0.50	0.0 - 0.050

Notes: a. Angle of attack feedback gain constant, K_α = 0.40 deg/deg.

b. Optimum gain determined from simulation.

Structural Resonance Tests:

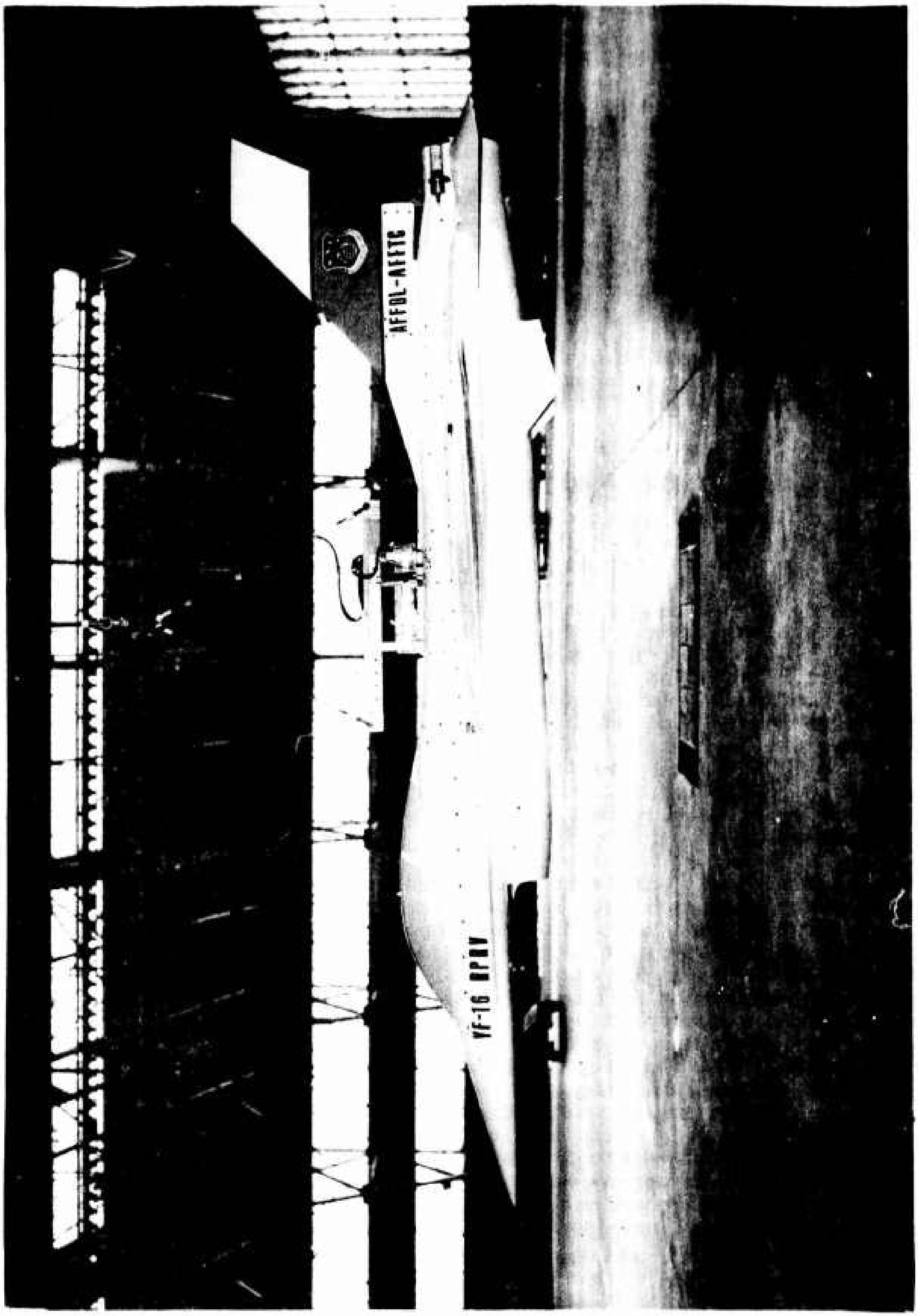
Structural resonance is a sustained, closed-loop oscillation of a motion sensor and a control surface at high frequencies (above 5 Hz) which is created when control system sensors detect small structural vibrations and the flight control system returns an opposing command back to the surface with 180 degrees phase lag. For the Drop Model, the "loop" includes the flight control system path from the sensor, through the downlink telemetry, the computer in the ground control station, and the uplink telemetry, to the surface; the loop is closed by the structural path from the surface back to the sensor. This is a structural vibration which is sustained by the flight control system, and which is independent of aerodynamic response to the surface deflection. Tests for structural resonance assume no aerodynamic effects and therefore ignore aeroelastic effects, unsteady aerodynamics, and pilot interactions.

Structural resonance testing was performed on the model prior to the first flight. The model was prepared for flight and suspended from above, both with and without the launch-rack mechanism. All internal model systems were activated and communication was established between the model and the ground control station. Each axis was tested independently with the feedback loop gains in the other two axes set to zero. Oscillations were induced mechanically by a sharp rap against the model fuselage, and the resultant oscillations were recorded. The feedback loop gain was then increased and the process was repeated. The maximum gains tested in each axis were: Kq = 2.6 deg/deg/sec; Kp = 1.0 deg/deg/sec; and K_r = 0.1 deg/deg/sec. Sustained oscillations were observed at 28 Hz in the pitch axis and 16.5 Hz in the roll axis. Since it was not expected that high frequency control surface responses would be required during the project, low pass filters were programmed into the elevator and flaperon command software to provide 12 db attenuation at the resonant frequencies. Subsequent tests showed that these modifications eliminated the structural resonances. It should be noted that any modifications to the flight control system or relocation of major model components or the sensors onboard the model would require repeating these tests.

Limit Cycle Tests:

A limit cycle oscillation is a sustained, low frequency (less than 5 Hz) oscillation of a motion sensor and a control surface which is created when the phase lag of the loop is 180 degrees and the loop gain is high. For the Drop Model, the "loop" includes the same flight control system path described above for structural resonance; the loop is closed by the aerodynamic path from the surface back to the sensor, that is, the aerodynamic response of the model to the deflection of the surface. Limit cycle testing is normally conducted using the actual flight vehicle to provide the sensor-to-surface portion of the control loop and a small computer (usually analogue) to simulate the surface-to-sensor aerodynamic closure of the loop. Thus, the tests automatically include the effects of mechanical and hydraulic control system nonlinearities, deadbands, and response characteristics which contribute to the phase lag. These tests assume a rigid vehicle and therefore ignore structural resonance, aeroelastic effects, and pilot interaction.

The Drop Model simulation described earlier in this report was programmed with an accurate representation of both the flight control portion of the loop (including the response characteristics of the hydraulic servoactuators) and the aerodynamic portion of the loop (full-scale YF-16 flight test results). Since this simulation included all the major sources of phase lag in the Drop Model system (the uplink and downlink telemetry delays were considered to be negligible), the limit cycle tests were performed on the simulator in a five-degree-of-freedom mode. The feedback loops in each axis were tested independently (the gains in the other two axes were set to zero), and each axis was tested at dynamic pressures ($\bar{q}$) from 0.0 to 325 psf (a factor of 1.5 times the maximum expected in flight and well above the maximum $\bar{q}$ observed with the model in a vertical dive). In the pitch axis, a matrix of pitch rate feedback versus angle of attack feedback gains was established to insure that each combination would be tested. Maximum feedback gains tested in each axis were; K_α = 0.8 deg/deg, Kq = 2.6 deg/deg/sec; Kp = 1.0 deg/deg/sec; and Kr = 0.1 deg/deg/sec. Results showed the Drop Model to be free from limit cycle oscillations in all axes for the conditions tested.


AFFDL-AFFTC
YF-16 RPRV

Model Weight, cg, and Inertia Tests:

The accuracy of the data reduction process used to determine the model stability and control derivatives and the accuracy of the ground-based simulation depended very heavily upon the accuracy of the weight, center of gravity, and moments of inertia data available on the model. These parameters had been measured on both models (tail numbers 002 and 003) by Atkins & Merrill prior to delivery to the Flight Test Center. The results of these tests are presented in table 6. Because the second model was disassembled, reassembled, and completely rewired, it was decided to reaccomplish these tests prior to flight 3-D-2. The procedures used were essentially identical to those described by Retelle and used for the X-24A Lifting Body[23]; those procedures will not be described here. Since the AFFTC had no suitable equipment for performing inertia tests on vehicles as small as the Drop Model, they were performed at the National Aeronautics and Space Administration/Dryden Flight Research Center (NASA/DFRC) using DFRC equipment and facilities. The results of these tests are also presented in table 6.

Table 6

RESULTS OF YF-16 DROP MODEL
GROSS WEIGHT, CG, AND INERTIA TESTS

	Contractor Tests Model 002	Contractor Tests Model 003	AFFTC Tests Model 003
Gross Weight lb	890.0	888.5	929.5
x cg Location, fs[a]	97.12	97.55	96.47
Percent MAC	36.00	37.10	34.80
y cg Location, bl[b]	0.00	0.00	ND
z cg Location, wl[c]	27.59	27.41	27.17
I_{xx}, slug-ft^2	35.7	35.7	40.7
I_{yy}, slug-ft^2	212.6	211.1	215.0
I_{zz}, slug-ft^2	221.4	219.6	251.0
I_{xz}, slug-ft^2	ND[d]	ND	1.5

Notes:

[a]fuselage station

[b]buttocks line

[c]waterline

[d]Not Determined

[23]Reference 2: Retelle, John P. Jr., Measured Weight, Balance, and Moments of Inertia of the X-24A Lifting Body, FTC-TD-71-6, Air Force Flight Test Center, Edwards AFB, California, November 1971.

FLIGHT TEST OPERATIONS

FLIGHT NUMBERING SYSTEM

The numbering system for the flight operations conducted during the Drop Model program was designed to specify which flight vehicle (tail number) was used, the type of mission, and the cumulative number of missions of that type flown to date. Since the Iron Bird was actually designated tail number 001, four tow qualification tests conducted with that vehicle were designated 1-T-1 through 1-T-4, and parachute qualification tests were designated 1-P-1 through 1-P-3, indicating that they were accomplished with model 001. The captive flights were numbered 2-C-1 through 2-C-3, indicating that they were accomplished with model 002, and the actual free-flight test operations (drops) were designated 2-D-1, 3-D-2, and 3-D-3, indicating that the last two flights were accomplished with model 003. Launch rack tow qualification flights and parachute qualification flights conducted with the two Iron Bombs (weighted cylinders) were excluded from this numbering scheme.

TOW QUALIFICATION TESTS

Tow qualification tests were conducted on the tow cable/launch-rack mechanism and on the various model configurations to be used during the Iron Bird and Drop Model flights; a summary of the tests is presented in table 7. The purpose of these flights was to insure that the launch helicopter would not encounter unexpected hazards while towing either the cable/launch rack or the model which might compromise the safety of the crew, the helicopter, or the model. A secondary purpose was to evaluate and refine operational procedures prior to the first Drop Model flight.

Tow qualification flights were conducted from the overrun portion of runway 30 at Edwards South Base, and the test route was parallel to the shoreline over the dry lakebed at low altitude. The test director maintained command and control from a radio equipped truck located at the test site. A fire truck and ambulance were dispatched to the site because the area was remote from normal base facilities. A safety chase helicopter accompanied the tow helicopter on the first four tests. Test sequences were conducted at 10-knot airspeed increments and included straight and level flight, climbs, turns, and descents. A ground based photographer filmed the tests as the helicopter took off and as it passed in front of him at each test condition.

The launch rack mechanism was cleared for tow up to 90 knots indicated airspeed (KIAS) and for retrieval with the winch at 45 KIAS on 25 March 1974. This test was excluded from the flight numbering system.

Three model tow qualification flights were performed on 28 March 1974. The test vehicle was ballasted to provide a cg at 25 percent mean aerodynamic chord (MAC), and the launch rack mechanism was adjusted to provide a level model attitude (statically). The Iron Bird was very stable in tow up to 80 KIAS throughout flights 1-T-1 and 1-T-2 with stabilator deflections of -2 degrees and -7 degrees, respectively. For flight 1-T-3, the cg was shifted to 35 percent MAC and the stabilators were deflected -20 degrees. The test proceeded well up to 80 KIAS, but as the helicopter decelerated through 40 KIAS a severe Dutch roll oscillation developed. The oscillation subsided with continued deceleration, and the tow qualification tests were temporarily suspended.

Table 7

SUMMARY OF TOW QUALIFICATION TESTS, YF-16 STALL/SPIN DROP MODEL

			TEST CONFIGURATION					
Date	Flight Number	MAX A/S (KIAS)	cg[a] (% MAC)	Attitude[b] (deg)	LEF[c] (deg)	Lt Stab[d] (deg)	Rt Stab[e] (deg)	Remarks
25 Mar 74	N/A[f]	90	N/A	N/A	N/A	N/A	N/A	Tow qualification of launch-rack and cable, retrieved rack at 45 KIAS.
28 Mar 74	1-T-1	80	25	0	0	-2	-2	Model stable
28 Mar 74	1-T-2	80	25	0	0	-7	-7	Model stable
28 Mar 74	1-T-3	80	35	0	0	-20	-20	Severe dutch roll oscillations during deceleration.
6 Dec 74	1-T-4	80	35	+5 to -10	0	-14	-20	Model stable only at -10 degrees pitch attitude.
10 Apr 75	2-T-5	80	35	-10	25	0	0	Model stable
20 Feb 76	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Safety and operational test of safety pin removal line.
18 Mar 76	N/A	80	N/A	N/A	N/A	N/A	N/A	Tow qualification of launch-rack and cable with safety pin removal line.

Notes:

a. Center of gravity

b. Model pitch attitude (static)

c. Leading edge flap deflection

d. Left stabilator deflection

e. Right stabilator deflection

f. Not applicable

Flights 1-T-1 and 1-T-2 were sufficiently successful to permit parachute qualification tests 1-P-1 and 1-P-2 with the cg at 25 percent MAC and stabilator deflections between -2 and -7 degrees.

On 10 December 1974, flight 1-T-4 was flown with the Iron Bird cg at 35 percent MAC and the stabilators set at -14 degrees left, and -20 degrees right to clear the configuration to be used on a subsequent parachute test. With the launch-rack mechanism adjusted for a level model pitch attitude (statically), oscillations began at 48 KIAS. The launch-rack mechanism was then adjusted to produce model pitch attitudes from +5 to -10 degrees; the Iron Bird was stable only at the -10-degree attitude up to 80 KIAS in level flight and up to 40 KIAS in a 500-foot per minute descent.

The description of the Iron Bird presented earlier in this report noted that there were no leading edge flaps on airframe 001. Because the initial model free flights were to be performed with the leading edge flaps deflected at 25 degrees, it was necessary to qualify that configuration for tow. Flight 2-T-5 was conducted on 10 April 1975 using the Drop Model (tail number 002) with deflected leading edge flaps. Because the leading edge flaps improved the stability characteristics of the model, the Dutch roll oscillations which occurred at high altitudes on an Iron Bird parachute qualification test were not encountered. (This flight was considered a tow qualification rather than a captive flight because of its primary purpose and because none of the model systems were activated during the flight.)

Prior to Drop Model free flight 3-D-2, a safety pin removal line was added to the helicopter tow/launch system to pull the safety pins and enable parachute deployment if the model was jettisoned. The safety and correct operation of this addition were verified on 20 February 1976. The Iron Bird (already damaged beyond repair during parachute qualification test 1-P-3) was mated to the helicopter, and the helicopter hovered with the Iron Bird several feet above the ground. The helicopter pilot then jettisoned the load while a photographer filmed the sequence with a high speed movie camera. The launch rack mechanism with the safety pin removal line was tow qualified to 80 KIAS and hoisted into the helicopter at 45 KIAS on 18 March 1976.

PARACHUTE RECOVERY SYSTEM TESTS

All parachute recovery system tests were performed over the precision impact range area (PIRA) with a planned landing on precision bombing target number 8 (PB-8). These operations were designed to test all functions of the parachute logic box (PLB) and the parachute deployment sequence from the firing of the drogue slug through and including repositioning to the horizontal attitude. For all three Iron Bomb tests, a safety/photo chase helicopter was positioned behind and to the right of the launch helicopter but at the altitude where drogue parachute deployment was expected to occur. For the Iron Bird parachute deployment tests, an A-37B safety/photo chase aircraft was used and the chase pilot employed the procedures described in a subsequent section of this report.

Iron Bomb Recovery System Tests:

The first low speed parachute test was performed using the Iron Bomb on 11 April 1974. The drogue parachute was damaged during deployment, and the resulting oscillation caused separation of the main parachute from the payload as the main parachute deployed. That Iron Bomb was destroyed on ground impact. The Recovery Systems Branch of AFFDL then assumed responsibility for parachute system development, and the

contractor-developed drogue parachute was replaced by a standard ribbon drogue parachute[24] from the BQM-34C Firebee drone.

A low speed parachute deployment test was conducted with the second Iron Bomb on 21 June 1974. Launch occurred at 9000 feet MSL (approximately 6500 feet AGL) and a completely successful deployment sequence followed a 9-second free fall. An equally successful high speed deployment occurred on 24 June 1974 from a launch altitude of 13,500 feet MSL. The drogue parachute deployed at a maximum dynamic pressure ($\bar{q}$) of 110 psf after a 17-second free fall.

Iron Bird Recovery System Tests:

Flight 1-P-1, a low speed parachute recovery system test, was performed on 25 June 1974. The Iron Bird center of gravity was adjusted to 25 percent MAC to insure that the model would be longitudinally stable, and the stabilators were set to -7 degrees to produce a low airspeed glide. Launch occurred at 7300 feet MSL and 80 KIAS, and the drogue parachute was deployed earlier than planned by the barometric switch. The deployment sequence was normal and the descent rate beneath the main parachute was approximately 13 fps. The Iron Bird suffered only minor damage on landing.

Flight 1-P-2 was flown on 2 July 1974 to verify that the model could be recovered from a high speed dive. Again, the cg was at 25 percent MAC but the stabilators were adjusted to -2 degrees to produce the dive. Launch occurred at 13,000 feet and 80 KIAS, and the model pitched over into a steep oscillatory spiral. The parachute recovery sequence was initiated after 17 seconds at a $\bar{q}$ of 160 psf, and drogue parachute deployment was normal; however, the main parachute ripped along a radial seam from the skirt all the way up to the apex. With this damage, the descent rate was approximately 19 fps and the Iron Bird sustained minor structural damage to the nose and to the stabilator hinge mounts. It was returned to the Atkins & Merrill, Inc. factory for repairs.

Flight 1-P-3, the final parachute recovery system test, was conducted on 2 December 1974 to verify that the drogue parachute would recover the model from a spin. The repaired Iron Bird was ballasted to provide a cg at 35 percent MAC and the stabilators were set to -14 degrees left and -20 degrees right to induce stalling and spinning moments. A Dutch roll oscillation appeared when the helicopter reached 15,000 feet MSL with the model in tow; the oscillations were severe enough that the Iron Bird was launched early. This test was successful in that the stall/spin gyrations were terminated by deployment of the drogue parachute, but the drogue parachute risers became wedged inside the parachute canister, thus preventing the drogue parachute from deploying the main parachute. The Iron Bird was extensively damaged on ground impact. A minor modification was made to the recovery system to insure that similar malfunctions would not occur.

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[24] Federal Stock Number 1670-079-0983 SP

CAPTIVE FLIGHTS

Captive flights 2-C-1 through 2-C-3 were performed on 29 August and 11 and 24 September 1975 with model 002. The flights were conducted in a rectangular pattern from the mating area (north of building 1830), across the lakebed and into the Precision Impact Range Area (PIRA) (see figure 6). After making a large circuit through the PIRA, the helicopter departed the area on the same course the model would have taken during an emergency lakebed landing, and descended very close to the lakebed surface. This pattern demonstrated that the command telemetry signal reception was adequate throughout the PIRA and the emergency landing pattern in the event that a lakebed landing would be necessary.

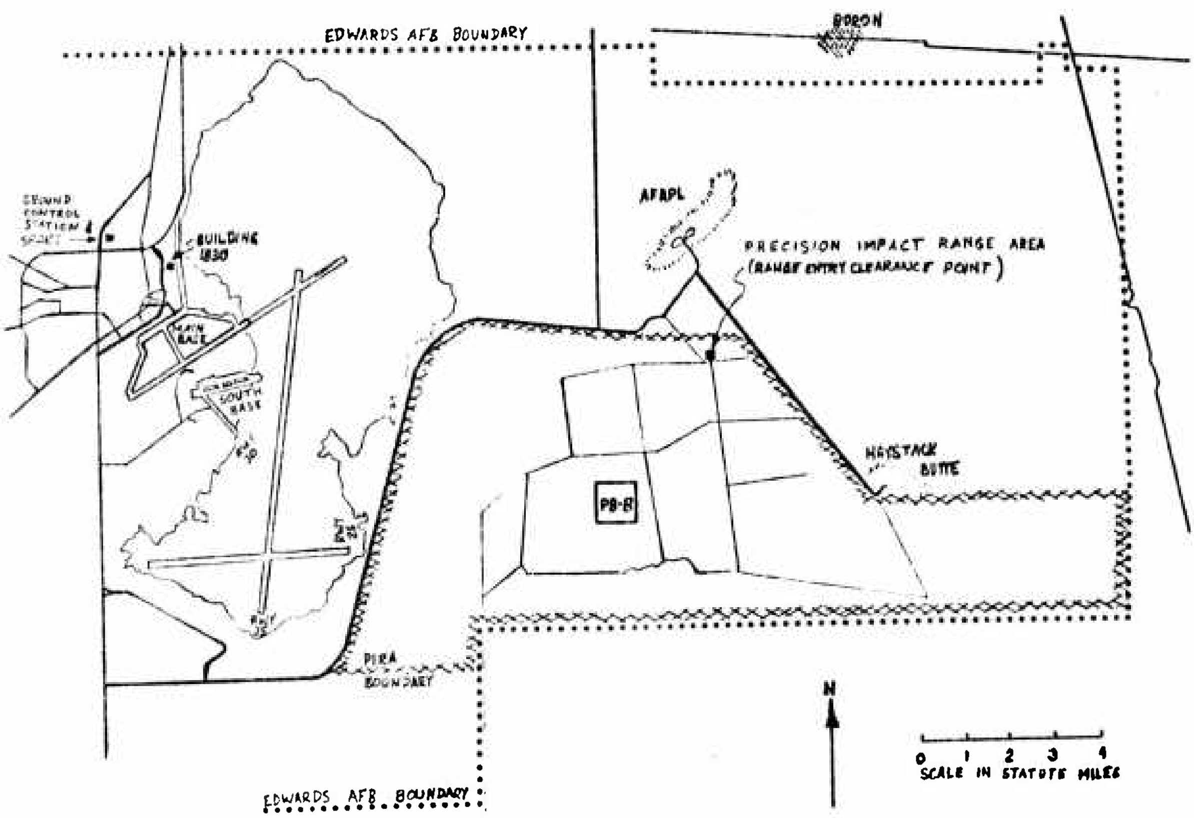


Figure 6 YF-16 Drop Model Area Of Operation

Flight 2-C-1 revealed an electromagnetic interference that distorted the command telemetry signal during tow. The signal was being reflected from the helicopter rotor blades down through the model canopy to the telemetry system components. Shielding was placed around the inside of the canopy and around the coaxial cable linking the receiver and decoder. Ground tests verified that this action solved the problem. Flight 2-C-2 revealed that helicopter electrical power was too noisy and too low in voltage to be used as an external electrical power source for the model. The alternate battery (described previously) was fabricated and carried aboard the helicopter to provide power to the model during climbout. Flight 2-C-3 revealed that the attitude gryo would drift significantly during the climbout to the launch altitude, but it was postulated that the model would be reasonably stable just before launch and that the gyro could be uncaged at that time even though a small error would be introduced. The magnitude and impact of the attitude gyro problem was not realized at that time. No other problems were discovered during flight 2-C-3.

During all three captive flights, episodes of model control surface fluctuations were sufficient to slew the model in yaw and to induce small lateral and longitudinal swinging motions; however, they did not present a danger to the helicopter. These fluctuations verified that control surface creep (slow drift of the surface away from the zero or streamlined position) would present no danger at low forward speeds.

Operation of the ground control station was satisfactory except that the altimeter and the vertical velocity indicator (VVI) responses were very noisy. The noise was reduced to an acceptable level by revising the altimeter drive routine and incorporating a smoothing routine into the VVI drive routine in the computer program. The television monitor display of the radar plotboard was found to provide adequate position and altitude information to enable proper command and control of the flight by the test director.

TYPICAL FLIGHT OPERATIONS

The test team activities which were common to all three model flight operations, from initial preparations to retrieval of the model and postflight debriefings, will be described below.

Flight Planning and Pilot Training:

Approximately three weeks before each flight, the project test engineer began to generate the flight plan using the fixed-base, six-degree-of-freedom simulator. The primary task was to determine a detailed sequence of maneuvers which would best accomplish the overall objective of the particular mission and produce the maximum amount of usable data, and which would not exceed the operational and safety restrictions which had been established for the program. For the initial flights, it was highly desirable to begin with the most benign maneuvers and build up to the more hazardous ones. It was also desirable to accomplish the more important maneuvers early in the flight so that only the less important data would be lost in the event of a system failure prior to completion of the entire flight plan. The test engineer spent up to 20 hours in the simulator developing an integrated flight plan which provided a reasonable compromise between these sometimes contradictory objectives and which also provided a moderate pilot workload with smooth transitions between flight maneuvers. He also established and adjusted the expected ground track of the model to

determine a no-wind launch point and to confirm that the model would remain within the operational area defined for the project. The AFFTC radar controlling agency (SPORT) was provided a map depicting this information to facilitate real-time radar control of the Drop Model flight.

Once the flight plan had been established, the model pilot spent up to 15 hours in the simulator preparing for the flight. He became intimately familiar with the flight plan (occasionally suggesting minor changes) and with the expected response of the model to each maneuver. He also practiced flying with selected inflight sensor or instrument failures (airspeed, altitude, or angle of attack) and he coordinated procedures with the safety chase pilot for attempting an approach and belly landing on Rogers Dry Lake in case the parachute recovery system failed. Since the test engineer was to help the pilot remember the exact maneuver sequence during the actual Drop Model flight, he was present during all pilot training sessions to coordinate procedures and to establish and practice the timing and wording of the verbal reminders desired by the pilot. It should be noted that flight planning and pilot training were of such importance that if sufficient simulator time was not available to allow adequate preparation (due to equipment malfunction or scheduling conflicts with other projects which shared the same facilities), the scheduled flight was postponed. Pilot training sessions were generally conducted once per day for two to three hours because of the pilot's other duties.

Model and Ground Control Station Preparation:

During the two weeks prior to a planned flight the Drop Model data sensors were calibrated and the proper operation of all model systems was verified. (Calibration and checkout of the accelerometers and gyros were performed in a laboratory prior to installing these devices in the model and were only repeated as necessary, and not before each flight.) The calibrations were inserted into the ground control station computer memory, and proper operation of the cockpit indicators and controls were confirmed. Uplink and downlink telemetry communication between the model and the ground control station was verified. A calibration tape of the downlink telemetry signal was produced; this recording presented those parameters which were to be displayed during the flight in real time on strip charts in the data acquisition facility. Each parameter was cycled back and forth at 1-second intervals between the predetermined maximum and minimum values presented to permit final, precise adjustment of the strip chart displays on the day of the flight.

System functional checks were conducted in accordance with the procedures in Checklist 4 (Appendix A), and took approximately a day and a half. All ground control station, model, and helicopter systems were checked out and their proper operation and interaction were confirmed. The correct calculation of the pilot's inputs and the feedback control system inputs, and the proper response of the model to the control surface commands and the discrete function commands was verified. Correct operation of the model monitor/launch box (MLB) was also checked. Once these checks were completed and the entire control loop, from the model to the ground control station and back to the model, was checked out, no further maintenance or unnecessary system operation was permitted on either the model or the ground control station. An action as insignificant as tightening an electrical connection or reseating a printing circuit board might compromise the integrity of the control loop and the rules established for the program required that the entire functional check be reaccomplished prior to flight.

When the functional checks were complete, the recovery parachutes were installed in the model. The main parachute was packed by the Recovery Systems Branch, AFFDL, with the aid of a hydraulic press. Since the main parachute bag stretched over a period of time making proper installation very difficult, a freshly packed parachute was delivered for each model flight. After the parachutes were installed, the pyrotechnic circuits were checked and a shorting plug was installed to insure that stray electrical signals would not inadvertently fire the devices. The pyrotechnic devices were then installed.

Scheduling:

Requirements for the launch helicopter, safety chase aircraft, airspace, radar and optical tracking, data acquisition, communications, and photographic support were coordinated through AFFTC Center Scheduling one and one-half to two weeks before a flight. Since two days were devoted to functional checks, last minute preparations, and preflight briefings, it was desirable to conduct these activities on a Monday and Tuesday and to perform the flight on Wednesday. This plan allowed slippage of the flight to Thursday, Friday, or Saturday if the functional checks disclosed a problem in the Drop Model system, if AFFTC aircraft or facilities became unavailable, or if the weather precluded the flight.

Preflight Briefing:

A comprehensive preflight briefing was conducted prior to each flight (usually on the afternoon before the scheduled flight). Present at the briefing were the test director, the test engineer, the model pilot, all the helicopter crewmembers, the launch box operator, the chase pilot, the photographer, the ground control station programmer, a member of the recovery crew, and a representative from the radar tracking facility. All appropriate times and radio call signs were presented, preflight checks were discussed, and all operational and communications procedures were coordinated. Flight safety considerations were discussed and all inflight emergency procedures were reviewed to insure that each crewmember and test team member had a correct and complete understanding of his responsibilities. Model recovery activities were also discussed.

Drop Model System Preflight:

On the day of the flight, final preflight checks were begun approximately four hours before the scheduled launch time. While preliminary checks were being conducted on the model and the ground control station individually, a member of the test team was at the data acquisition facility checking and calibrating the strip chart recorders using the calibration tape described previously. Coordinated ground control station/model/data acquisition facility checks were conducted in accordance with Checklist 7 (Appendix A). Appropriate checks were performed using internal model power: spot checks were made on each instrumentation calibration when possible, and system checks were performed on the model telemetry, hydraulic flight controls, and electrical systems. Proper operation of the feedback control loops was again verified. The launch-rack mechanism, tow cable, and lower umbilical cable were inspected. The model was then wheeled out to the mating area on its dolly.

Helicopter/Model Mating:

The UH-1N helicopter arrived in the mating area approximately one hour before scheduled launch time; all Class II modification equipment had been installed and secured in the helicopter the previous afternoon (Checklist 8, Appendix A). The model was wheeled to within 6 feet of the helicopter, the tow cable was attached to the cargo hook, and operation of the pilot's jettison button was checked. The upper and lower umbilical cables were checked for smooth separation, proper release of the launch-rack mechanism was verified, and all functions of the model monitor/launch box were checked out. The other lines and lanyards described above in the Helicopter Systems section were installed (Checklist 9, Appendix A).

Communications Procedures:

All communications between the helicopter pilot, the chase pilot, the model pilot, the test director, the test engineer, the radar controller, the range safety officer, and the model recovery team were conducted on a single UHF radio frequency. Transmissions on this frequency were kept to an absolute minimum. An interphone system also connected the ground-based stations above, and was used for all non-critical communications.

Climbout and Launch Procedures:

When the mating procedures were complete, the helicopter took off, gently lifted the model from its dolly, hovered while the nose of the model was latched down, and then departed for the launch area. As the helicopter climbed out toward the launch point, it was joined by the A-37B safety/photo chase aircraft. The helicopter climb profile was closely monitored by the test director and the test engineer, and if the model did not have sufficient altitude to glide to the desired parachute deployment point at best range airspeed in the event of an emergency launch, the helicopter pilot was directed to fly a climbing racetrack pattern to gain altitude. The required altitude varied as the distance from the model's position to the desired parachute deployment point (PB-8). The helicopter was vectored to the planned launch point by the radar controller (SPORT). Both the planned launch point and parachute deployment point were adjusted for current wind conditions just prior to the flight to account for winds. The radar controller transmitted an approximate countdown and the model attitude gyro was uncaged one minute prior to launch. Final ground control station, model, and data acquisition system checks were performed as described in Checklist 10 (Appendix A). When the test director was satisfied that all required systems were operating properly, he transmitted a clearance to launch. When the chase pilot maneuvered his A-37B into the optimum position for launch, he directed the launch box operator (LBO) to launch the model. After launch, the model pilot flew the model to the adjusted parachute deployment point while performing the planned data maneuvers. For all flights, the planned landing point was PB-8. Deviations from these standard procedures and the important in-flight events will be described below for each model flight.

Immediately after each flight, a Rawinsonde weather balloon was released to collect data on wind and atmospheric conditions for input to the tabulated radar position data and for use in postflight computer data manipulations.

Safety/Photo Chase Procedures:

The A-37B was selected as the safety/photo chase aircraft for the Drop Model because it was the only available aircraft capable of escorting the model to the 16,500-foot launch altitude, approximating the model's descent rate and maneuverability, and maintaining visual contact with the model at the model's stall speed (70 KIAS). Other aircraft routinely available at the Flight Test Center were capable of fulfilling one or two of these requirements, but not all three. An AFFTC photographer occupied the right seat of the A-37 to provide motion picture documentation of each flight.

The A-37B was scheduled to takeoff at the same time that the helicopter departed with the model in tow and the rendezvous was accom-

plished during the climbout. It carried full internal fuel, full wing-tip tanks, but empty pylon tanks; this offered the best compromise between maneuverability and loiter time (in the event of a minor pre-launch delay). Since the A-37B was not able to maintain the 45 KIAS forward speed of the helicopter prior to launch, it flew a racetrack pattern around the helicopter and model. The optimum position for the chase aircraft at launch was offset behind and below the model on a parallel heading and at the A-37B's minimum safe airspeed. During the Iron Bird parachute tests and model flights 2-D-1 and 3-D-2 the chase pilot simply tried to adjust his racetrack pattern to be at the optimum position at launch by listening to the approximate launch countdown transmitted by the radar controller (SPORT). Since a launch delay of one minute was not considered excessive and was occasionally required for completion of the prelaunch checklist, the chase aircraft was often well out of position at launch. For flight 3-D-3, the prelaunch checks were completed and a clearance to launch was issued by the test director, but the launch was actually commanded by the chase pilot when he was in the optimum position; this procedure worked well.

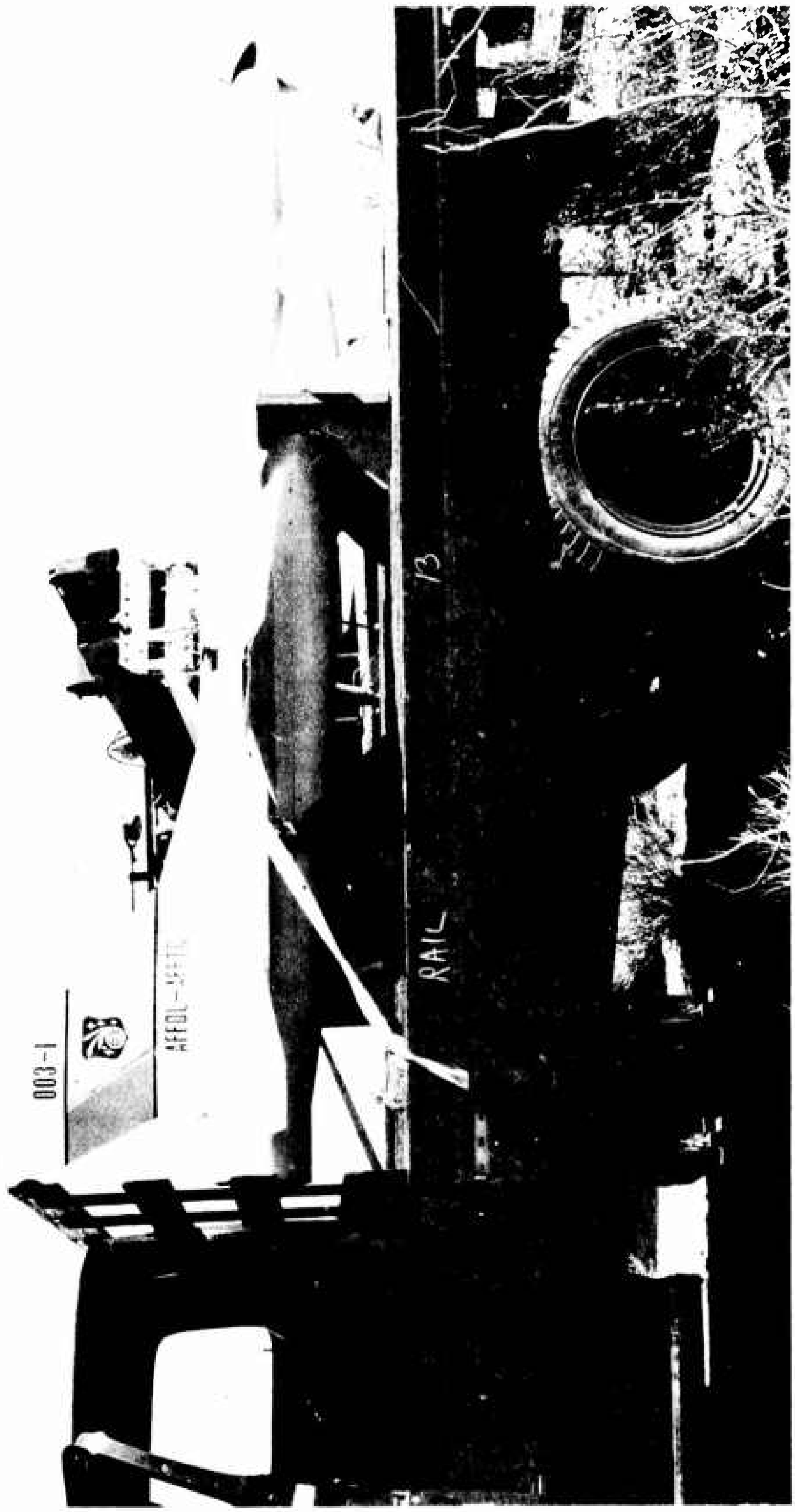
During the flight, it was the duty of the chase pilot to maintain visual contact with the model and advise the test director of any unsafe or unusual condition and, if possible, to provide a stable platform for the photographer. This proved to be an extremely difficult task. Because of the great maneuverability of the model and the possibility of losing control of the model from the ground station, it was necessary for the chase aircraft to remain a considerable distance from the model; but that increased the difficulty of maintaining visual contact and photographing the model. After initiation of the parachute recovery sequence, the chase pilot provided advisories on the operation of the recovery system and the photographer filmed the sequence to landing. The chase pilot then directed the launch helicopter to the model landing site and returned to base. If the parachute recovery system failed to deploy, it became the duty of the safety chase pilot to direct the model pilot as he attempted an emergency landing on lakebed runway 25 with no visual cues.

Model Retrieval:

The launch helicopter landed near the model and the launch box operator (LBO) approached the model to install the pyrotechnic shorting plug and turn off the hydraulic motor/pump and the main electrical system. With the LBO again onboard, the helicopter took off and directed the model recovery team to the landing site, then retrieved the pilot and drogue parachutes and returned to base.

The recovery team was headed by a Drop Model instrumentation technician who was familiar with the model. It included an explosive ordnance disposal (EOD) specialist, a range safety representative, a driver/operator for the six-wheel-drive wrecker, and a driver for the ton-and-a-half flatbed truck. The team monitored the progress of the flight and communicated with the helicopter pilot and the range controller via UHF radio.

After the EOD specialist verified that all the pyrotechnic devices had been fired (or removed any unspent devices from the model), and documentary still photographs were taken, the main parachute was released from the model and carefully gathered up. A spare launch-rack mechanism was attached to the model and the wrecker lifted it onto cradles on the flatbed truck. The model was secured to the truck with 2-inch wide cargo


RAIL

straps and the entourage returned to the base.

Mission Debriefings:

Immediately after the model landed, a technical debriefing of the model pilot was conducted by the test engineer. Specific questions on the simulation and pilot training, the prelaunch operations, and the response of the model during each of the flight planned maneuvers had been prepared prior to the flight. The pilot was asked to respond on tape to each question. The test engineer also posed questions about any unplanned maneuver or deviations from the flight plan. The pilot was encouraged to offer any other comments or suggestions he felt appropriate.

A general postflight debriefing of all mission participants was then conducted on tape. Present were the model pilot, the helicopter crew, the LBO, the chase pilot and the photographer, the test director, the test engineer, and all available members of the Drop Model test team; the radar controller was invited to this debriefing, but his presence was not required. The entire mission was reconstructed and each participant gave his account of the flight events. Suggestions and criticisms were solicited and occasionally resulted in highly beneficial changes to the operation.

FIRST MODEL FLIGHT

Mission Preparations:

Flight 2-D-1 was conducted on 3 October 1975. The objectives were to examine the handling qualities of the free-flight model, to acquire stability and control derivatives between 8 degrees and 18 degrees angle of attack, and to make a general comparison of the response of the model to simulator predictions.

The preflight and operating procedures suggested by the contractor were accomplished, and the helicopter departed the mating area north of building 1830 with the model in tow. The attitude gyro was uncaged prior to takeoff and it was allowed to drift during the climbout. The helicopter was able to attain sufficient altitude throughout the climb to enable the model to glide to the parachute deployment point in the case of an emergency launch. At one minute prior to launch, the attitude gyro had drifted more than 5 degrees in pitch and more than 15 degrees in roll. The gyro was caged, and then uncaged at 10 seconds prior to launch. Indications were that the model was receiving a strong uplink signal, internal battery voltages were satisfactory, the angle of attack and rate feedback loops were operating properly, and the control surfaces were responding to uplink telemetry commands. Thus, all launch requirements were satisfied and the model was launched on command from SPORT.

Flight 2-D-1:

The launch transient was very mild. The angle of attack increased to 9 degrees as the vertical velocity increased, and the model began to pitch over to align itself with the relative wind. At 3 seconds after launch, all control surfaces drove to the zero or streamlined position and remained. The model departed immediately and entered a highly oscillatory spin. The cockpit indicators in the ground control station reflected the pitch oscillations and the direction and magnitude of the yaw rate. Full-scale YF-16 spin recovery procedures were attempted, but

no commands were reaching the control surface actuators so the drogue parachute was manually deployed. Flight time from launch to drogue parachute deployment was 69 seconds.

Parachute Recovery and Impact Damage:

The drogue parachute was deployed at 7000 feet MSL when it became evident that model control would not be regained. The main parachute command was transmitted 7 seconds later, and the main parachute deployed approximately 200 feet above the ground 17 seconds after the drogue parachute. The model impacted the ground simultaneously with the first billow of the main parachute in a nosedown attitude.

The forward fuselage fiberglass shell, the pitot boom and other ADS components, both radar transponder antennas, both telemetry antennas, the noselift mechanism, the main and auxiliary batteries, the servo-controller, and the instrumentation power supplies were destroyed. Because of the extent of the structural damage, model 002 was not repaired, but the undamaged components were used as spares for model 003 throughout the rest of the program.

MODEL SYSTEMS REVIEW

After the first flight, the test team performed a comprehensive review of all the model hardware components, their functions, and their integration into the Drop Model system. It became evident that many discrepancies existed between the contractor's recommended operating procedures and the manner in which the hardware actually operated, particularly in the model control logic and the parachute deployment logic systems. The procedures did not indicate that the parachute recovery system safety pins also affected the model control system enabling logic. Prior to the first flight, it was understood that both model control and parachute deployment would be inhibited for the first three seconds of flight, but these were thought to be entirely separate functions and that only umbilical cable separation was required to enable model control. Postflight investigation revealed that the parachute recovery system time delay did, in fact, affect the model control enabling logic. Design of the parachute logic circuit was found to be reversed so that model control was permitted only with the parachute recovery system safety pins installed and for the first three seconds after they were removed. It was this logic error which inhibited model control on the first flight.

It was known prior to the first flight that initiation of the manual parachute deployment function also inhibited all of the automatic deployment features. This was considered to be undesirable but not critical; the system was modified before the second flight to insure that the automatic deployment signals could not be inhibited in any way after a normal launch or emergency jettison.

It was also known that there was a 10-second delay in the main parachute deployment circuit, but the exact operation of this delay was not completely described. It was understood that the 10-second timer began when the drogue parachute command was received at the parachute logic box (PLB) and that the main parachute could be deployed manually any time after the expiration of that 10 seconds. In fact, the timer began only after the main parachute deployment command was received in the PLB and, thus, actual parachute deployment was delayed until 10 seconds after the deployment command was received. It was this delay

which inhibited main parachute deployment until there was insufficient time and altitude to allow the main parachute to decelerate the model before ground impact.

As a result of these discrepancies it was decided to suspend further flights until the second model (tail number 003) could be completely disassembled and all components thoroughly bench checked and recalibrated. During this process, model documentation was updated as time permitted and more thorough maintenance documentation and configuration control procedures were adopted. The model control logic, the parachute deployment logic, and other hardware discrepancies were corrected and the model was completely rewired as it was reassembled. The parachute system pyrotechnic circuits were modified to enable final parachute logic and pyrotechnic circuit checks to be accomplished immediately prior to helicopter mating (with the pyrotechnic devices installed). Prior to completion of this modification, any checks performed after the pyrotechnic devices had been installed would have fired the devices.

PROGRAM REVIEW

Concurrently with the model hardware review, a comprehensive, critical review of all phases of the Drop Model program was conducted. Nine committees of three or four members each were formed to probe the following areas: Program Command and Control, Launch System and Helicopter Interface, Mechanical Systems, Recovery Systems, Instrumentation, Simulation, Software, Telemetry and Ground Control Station, and Cockpit Presentations/Procedures and Pilot Training. Committee members were chosen for their experience and expertise in the above areas and because they had no previous substantial participation in the Drop Model program. Available documentation and brief systems descriptions were provided to each committee by the test team and the committee then conducted an independent evaluation in its specific area. A conscious effort was made by the test team members to avoid influencing the thought processes of committee members. Each committee submitted written recommendations; in most cases the recommendations were implemented, but a few were found to be inappropriate, too costly for the Drop Model budget, or simply not feasible.

In addition to the known deficiencies in the areas of manpower, ground control station reliability, hardware documentation, and maintenance record keeping, several review committees pointed out deficiencies in the preflight system checkout procedures and the command and control of the test mission. A rigid, step-by-step, challenge-and-response checklist was established for each system component and for each phase of the checkout procedure. These checklists are presented in Appendix A. Command and control procedures were revised to improve communications among test team members and to delineate decisionmaking and advisory responsibilities. The committees' recommendations were compiled and a brief written summary, indicating the action taken in response to each recommendation, was prepared by the test team.

Prior to the second flight, two practices were conducted in which a complete test mission, from preflight checks to model shutdown, was simulated. All test team members performed their duties as if it were a real flight, and several inflight emergencies and system failures were simulated.

A formal safety review was conducted on 2 March 1976, and a second Drop Model flight was authorized.

SECOND MODEL FLIGHT

Mission Preparations:

Specific preparations for flight 3-D-2 began on 5 April 1976 in anticipation of a 21 April flight. The objectives of the flight remained the same as for the first flight, but the sequence of maneuvers was altered at the suggestion of the model pilot to minimize the airspeed/angle of attack changes required. The planned maneuver sequence is presented in Appendix A. On 15 April, the flight was postponed indefinitely while AFFDL conducted a review of the safety precautions taken by AFFTC and clarified the reporting procedures required in the event of another unsuccessful flight attempt. Clearance to fly was received on 26 April, and the flight was rescheduled for 5 May. Functional checks of the model and the ground control station were performed on the 3rd and 4th, and the mission briefing was conducted on the 4th, but inclement weather prevented the flight on the 5th, 6th, and 7th of May. Flight 3-D-2 was accomplished on 8 May 1976.

Preflight and mating operations proceeded normally, but very shortly after the helicopter departed the mating area with the model in tow, the upper umbilical cord separated from the lower umbilical cord and three amber caution lights and the red warning light illuminated on the model monitor/launch box (MLB). The helicopter pilot chose not to jettison the model because he was in a stationary hover just a few feet above the ground. Jettisoning the model would have caused the drogue gun to fire when the safety pins were pulled and the barometric switch sensed an altitude below 6000 feet; deployment of the pilot and drogue parachutes might have endangered the helicopter. Instead, the pilot returned the model to its dolly and landed nearby. A complete mating procedure was reaccomplished, and the helicopter departed again.

The test engineer requested one climbing racetrack pattern to enable the model to glide to PB-8 if an emergency launch was required. The climbout was to be conducted with the attitude gyro caged, but the model was apparently receiving intermittent cage and uncage signals and the gyro responded to them. At 30 seconds prior to launch, an uncage command was transmitted and the gyro responded, but it was very unstable and began to precess rapidly in both pitch and roll. The launch was aborted and the gyro was caged. The gyro then began to respond normally to cage and uncage commands and to provide adequate attitude information so another attempt was made to launch the model. The launch was delayed approximately 40 seconds due to UHF radio communications problems, and as a result, the safety/photo chase aircraft was not in position to observe or photograph the launch.

Flight 3-D-2:

Launch occurred from 16,200 feet radar altitude (16,100 feet indicated pressure altitude). The launch transient was mild with no tendency toward an abrupt or violent separation. As the model pitched over and airspeed increased, the model pilot attempted to establish 18 degrees on the cockpit angle of attack indicator. He controlled the descent rate at 13,000 feet to set up for the first maneuver at 110 KIAS and 14 degrees α, but because of the ADS and attitude gyro problems mentioned earlier, the cockpit airspeed, angle of attack, and attitude relationships did not reflect the simulator predictions. The pilot and the flight test engineer decided to modify the flight plan in an attempt

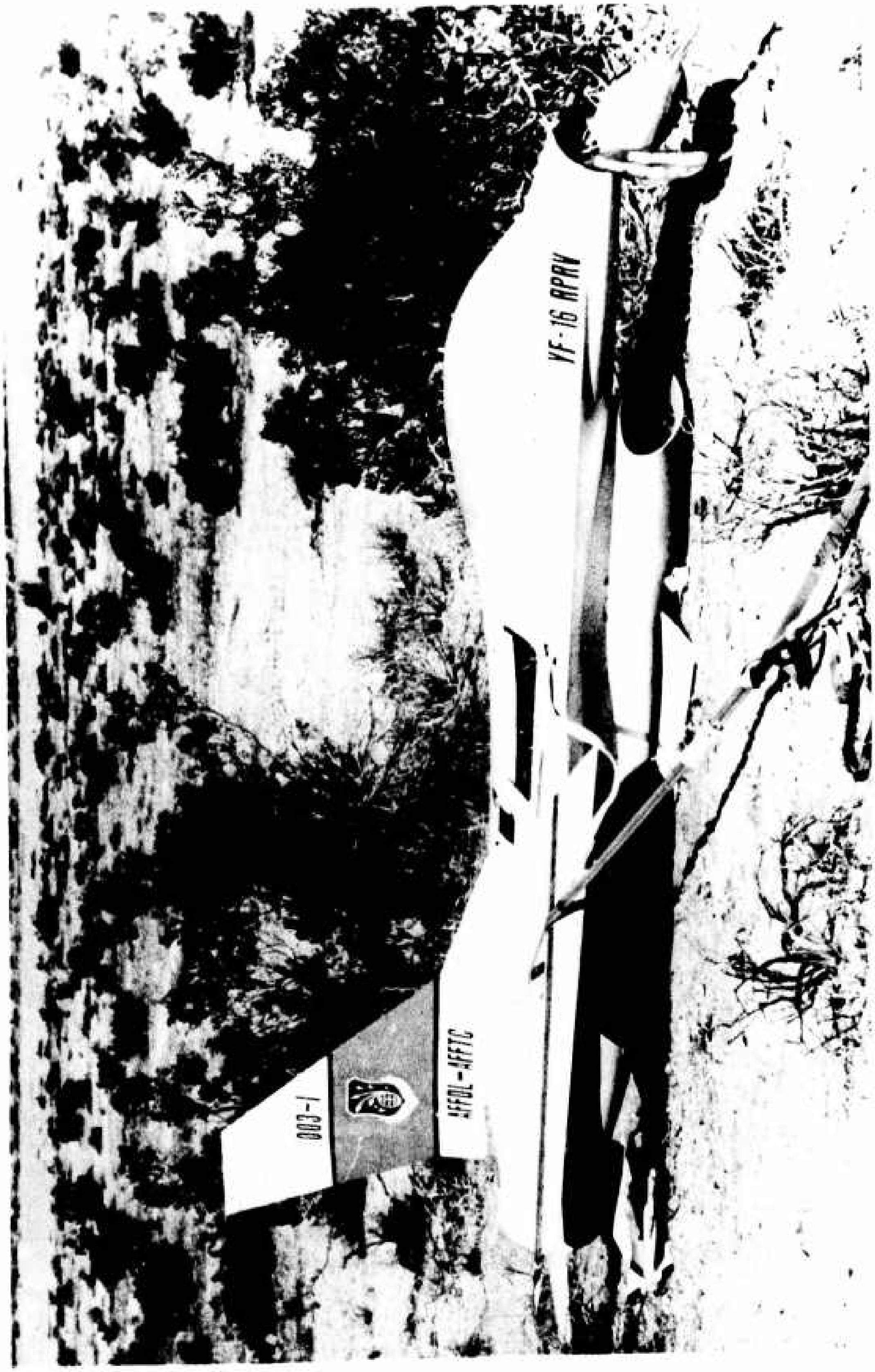
to analyze the discrepancies and quickly determine which of these parameters were in error. Constant indicated angle of attack descents were flown, but the indicated airspeed information never stabilized (probably because both sensors had become temperature dependent). The model began a shallow left turn at 11,500 feet radar altitude, possibly because the gyro precessed in roll and the pilot was attempting to maintain level flight on the cockpit attitude indicator. At 10,000 feet SPORT directed a right turn, and the pilot complied by banking approximately 15 degrees to the right. This arrested the turn briefly, but the radar ground track indicated that the model again began a left turn in spite of the indicated 15-degree right bank. By increasing his indicated bank angle to 30 degrees, the pilot was able to generate a moderate turn rate to the right. At 8000 feet, reception of the uplink telemetry signal at the model became erratic and the model performed violent pitch and roll gyrations then went into a steep descent before control was regained. Drogue parachute deployment was commanded from the ground one second after the onboard barometric sensor had initiated the parachute deployment sequence at 6000 feet radar altitude. Flight time was 3 minutes, 35 seconds.

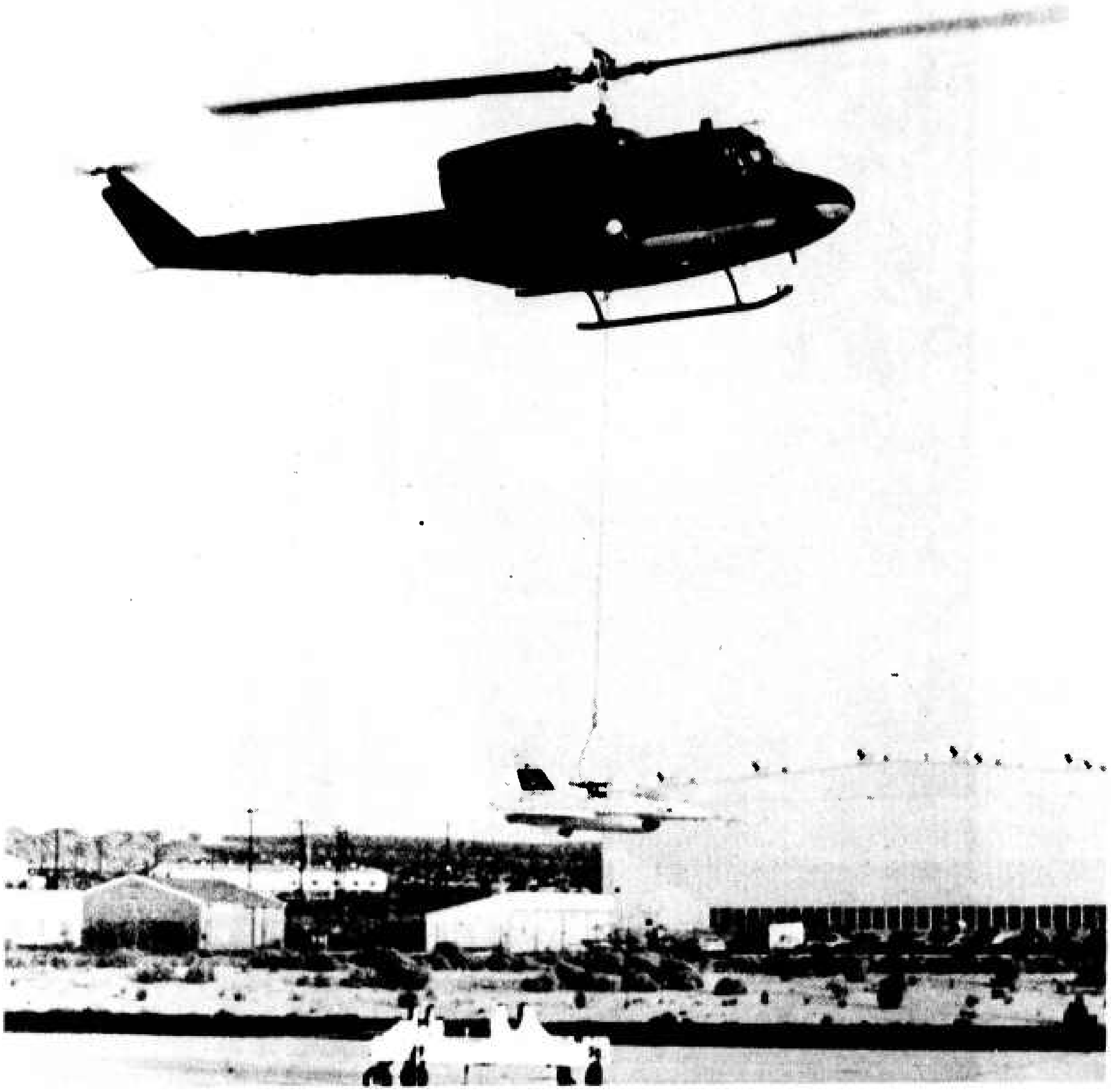
Parachute Recovery and Landing Damage:

The recovery system operated normally and the model landed on level terrain with moderate damage. The simulated AIM-9 missiles and launch rails were torn from the wingtips by the landing "g" forces and the ventral fins were sheared off. The strakes forward of the wing roots were split at the bond line, and some minor cracks appeared at the juncture of the underbelly fiberglass skin and the main fuselage skin. The aluminum hinge on which the nose rotated upward was sheared off and the angle of attack vane was broken when the nose section and pitot boom contacted the ground. Model retrieval and postflight debriefings were conducted as described above.

Model Refurbishment:

A complete damage assessment was performed on the model. The fiberglass skin and crushable foam core were removed from the underbelly. Visual inspection revealed that the foam had sustained no permanent deformation and, hence, had absorbed very little of the landing impact. No internal damage to the model structure or systems was discovered. A new air intake, fiberglass skin, foam core, and ventral fins were installed and all other fiberglass damage was repaired. Considerable effort was expended to retain the original external configuration of the model and to eliminate any obvious seams or blemishes at the juncture of the underbelly and main fuselage skins. Jigs were constructed to facilitate proper alignment of the ventral fins. The area to which the nose hinge was attached was strengthened by bonding a large aluminum plate inside the fuselage fiberglass to distribute the forces and to preclude future damage. A new hinge was machined from tempered steel. The repaired areas of the fuselage were spot painted and large areas of the upper and lower surfaces of the left wing and stabilator were painted international orange to improve visibility from above. The right wing and stabilator were painted white to assist in visual determination of the model attitude and flightpath. Model refurbishment and painting was completed in five weeks.


YF-16 RPRV
AFFDL-AFFTC



THIRD MODEL FLIGHT

Mission Preparations:

After completing the modifications to the ADS and the gyro cage and uncage command circuits, flight 3-D-3 was scheduled for 28 July 1976. The objectives of the flight were to acquire the data necessary to evaluate the operation of the ADS, to determine the gliding performance of the model at three flight conditions (to update the simulator for future flights), and to determine the longitudinal and the lateral directional stability and control derivatives of the model at four flight conditions. The planned maneuver sequence is presented in Checklist 11, Appendix A.

During the final steps of the functional preflight checks on 27 July, a failure occurred in the interface unit of the ground control station. Though it was a minor problem, troubleshooting and repair procedures invalidated the previous checks and necessitated reaccomplishment of the entire check. The flight was postponed to 31 July 1976.

Preflight and mating operations proceeded normally. The attitude gyro was uncaged shortly before the model was lifted from its dolly to assess the gyro drift rates under tow conditions. During the 25-minute climbout, the gryo drifted 10 degrees in pitch and 30 degrees in roll and heading, so it was caged 5 minutes before launch. It was uncaged 2 minutes before launch and provided adequate attitude information for flight. The clearance for launch was delayed 5 seconds due to an interphone communications problem between the data monitor and the test director, but the chase pilot and photographer were able to maintain visual contact.

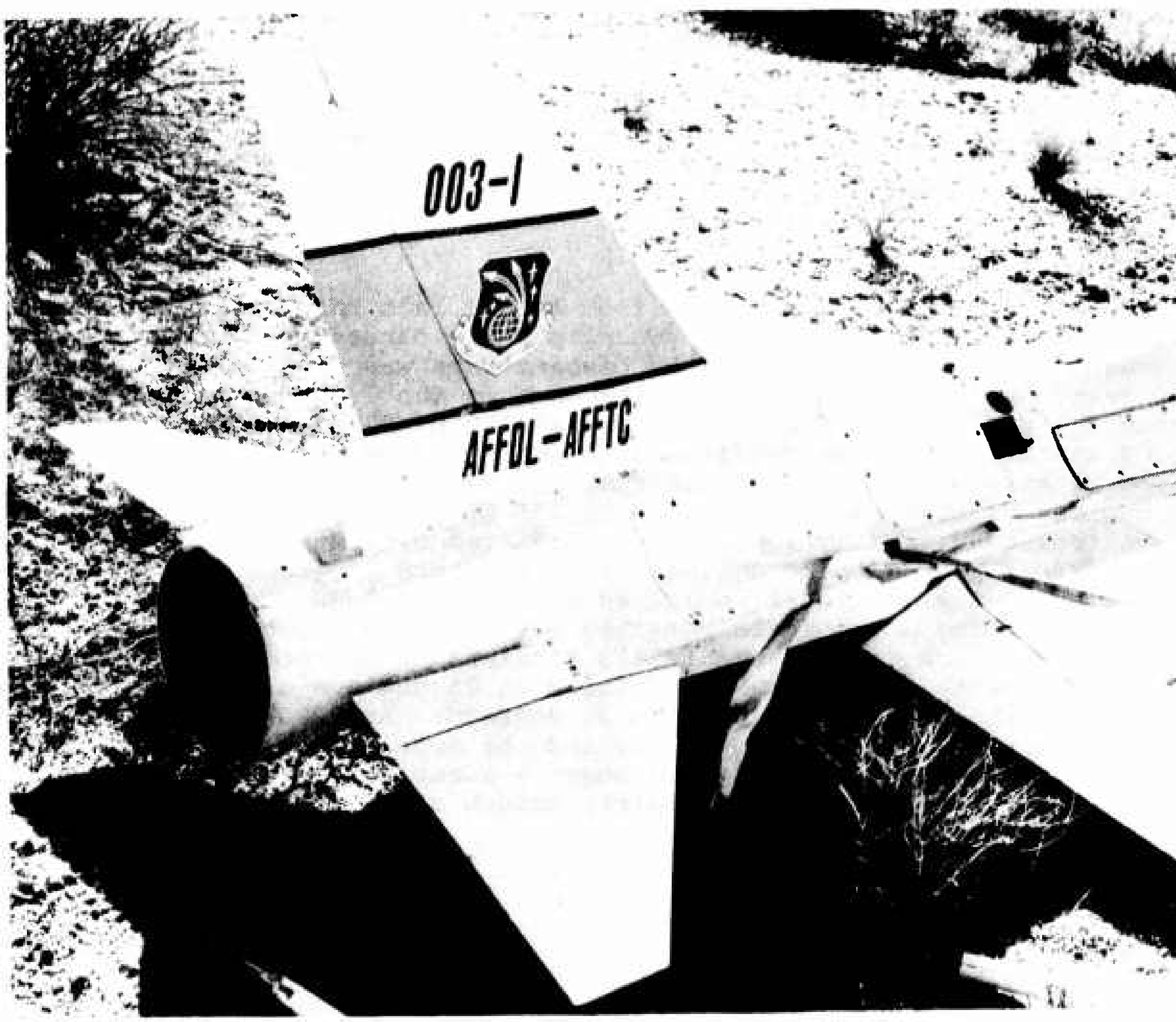
Flight 3-D-3:

The flight began with a launch from 16,400 feet radar altitude in an indicated right bank and right sideslip which caused a 20-degree right heading change by the time the descent rate was arrested at 13,900 feet. The model pilot corrected back to the left and established a constant airspeed, wings level descent at 150 KIAS and 8.5 degrees angle of attack. At these conditions he performed an elevator doublet followed by aileron and rudder doublets. He then began a right turn at 20 degrees of bank and decelerated to 130 KIAS and 11 degrees α. The turn took considerably longer than predicted by the simulator and the turn rate appeared to be decreasing as the turn progressed. The pilot rolled to a wings level indicated attitude at 9300 feet and the model began turning left, again possibly due to a precessed gyro. At 8700 feet the pilot decelerated to 118 KIAS and 13 degrees α and at 8000 feet he began a right turn initially at 25 degrees of bank, then increased the indicated bank angle to 35 degrees. At 7200 feet, the uplink telemetry signal became erratic and the model again performed violent pitch and roll gyrations and began a steep dive. The drogue parachute was deployed by the barometric switch after 3 minutes, 24 seconds of flight.

Parachute Recovery and Landing Damage:

The main parachute deployed normally but as the model repositioned to the horizontal attitude, one of the parachute risers became caught between the top of the rudder and the vertical stabilizer causing the model to assume a 30-degree left bank and 30-degree nosedown attitude beneath the parachute. The noselift mechanism worked properly. The model first contacted the ground on the forward fuselage at the nose hinge line, fracturing the fiberglass bulkhead, breaking the downlink telemetry antenna, cracking the canopy, and breaking the lower C-band radar transponder antenna. It then landed on the air intake and underbelly, shearing off the ventral fins, cracking the strakes, and separating the AIM-9 missiles and launch rails as in the previous flight; a small portion of the top of the vertical stabilizer was broken off by the parachute riser. No visible damage was done to the internal model systems.

The model was not repaired because program termination was expected, but postflight calibrations were performed on all instrumentation sensors to verify the validity of the recorded telemetry data.



FLIGHT TEST RESULTS

The quality of the downlink telemetry signal recorded at the data acquisition facility was adequate on all three Drop Model flights. An assessment of the accuracy of the data and the results of each flight will be presented in this section.

FLIGHT 2-D-1 RESULTS

The controlled portion of the first flight lasted only 3 seconds which was not adequate to make a realistic determination of the accuracy of the data acquired. Since the sensors were calibrated before the flight, the results of the flight will be presented as though all data acquired was correct.

As mentioned above, the model control surfaces became locked in a streamlined position 3 seconds after launch causing the model to pitch up, depart, and enter a highly oscillatory, nosedown spin. The upper limit of the angle of attack sensor was 80 degrees, and the angle of attack consistently exceeded that value; the minimum value observed was 15 degrees. Pitch angle oscillations ranged from -90 degrees to -10 degrees and the yaw rate was cyclic with the pitch oscillations, peaking at 300 degrees per second. Eight full turns were completed before the drogue parachute terminated the spin maneuver. The characteristics of the spin were similar to those encountered during the 2.5-turn spin performed by the full-scale YF-16. The phase and magnitude of the pitch and yaw oscillations were similar to the full-scale YF-16, but the model yaw rate was considerably greater than the rate expected after applying the Froude number scaling laws.

FLIGHT 3-D-2 RESULTS

On flight 3-D-2, a heater blanket, which stabilized the temperature of the air data system pressure transducers and signal conditioning amplifiers failed. Any quantitative analysis performed on the data from this flight would be meaningless without information on the flight conditions (airspeed, altitude, and angle of attack) of the model. However, a qualitative assessment of the procedures used and the operation of the model systems will be made.

The primary result of the flight was that it demonstrated the capability to control the Drop Model from the ground control station with reference to the telemetered data displayed on the cockpit instruments. The flight also revealed the reduced gliding performance of the model which was to be quantitatively analyzed on the next flight The operational procedures used by the test team (described above under Typical Flight Operations) were well suited for the proper conduct of a model flight. All test team activities were well coordinated and executed.

Besides the ADS and the attitude gyro problems, the yaw rate information appeared to be offset by approximately 5 degrees per second possibly due to an incorrect calibration. The cause of the weak or intermittent uplink telemetry reception at low altitude was not determined. All other model systems worked well. Only two problems were noted in the ground control station; the indications of the cockpit altimeter lagged significantly behind the pressure altitude sensed by the model, and the uplink surface command signals contained spikes.

These commands were of extremely short duration (one or two PCM telemetry frames, or 12.5 milliseconds) and the model control surface responses were of such limited amplitude and duration that the model reaction was not observed by the pilot. The commands and surface deflections were observed in real time on the strip recorders (see figure 7) but they were thought to be data dropouts of the PCM downlink telemetry signal.

FLIGHT 3-D-3 RESULTS

Only the attitude gyro problems, the spurious control surface commands (spikes), and the weak or intermittent uplink telemetry reception at low altitude continued through the third model flight. As described earlier, the temporary installation of an accurate differential pressure transducer and other modifications to the air data system greatly improved the data acquisition and analysis capability. For this flight, the model gross weight was 929.5 pounds, the cg was located at 34.8 percent MAC, and the leading edge flaps (LEF) were full down at 25 degrees.

Because of the unknown bias which existed in the model attitude information at launch, no upwash correction was applied to the angle of attack data. In addition, no pitch rate corrections were made. Hence, all angle of attack data presented for the Drop Model will be indicated angle of attack. Position error was not determined for the airspeed or altitude data because stabilized flight was not achieved for a sufficiently long period of time to permit accurate calculation of these corrections from the radar data, and pace aircraft operations were considered unsafe because of the violent gyrations experienced by the model when the uplink telemetry signal was lost. Only indicated altitude and airspeed will be presented for the model.

Launch:

Launch occurred from 15,800 feet indicated (16,400 feet radar altitude) at 50 knots indicated airspeed (KIAS). The model pitch angle was -9.5 degrees and the indicated angle of attack was -11.5 degrees (the helicopter was in a slight climb). Figure 8 presents a time history of the telemetry data from the first 19.5 seconds of flight (launch actually occurred at the 0.5 second point). Initial stabilator deflections were generated by the combinations of angle of attack and pitch rate feedback calculated by the computer. First pilot inputs were made after 4 seconds of flight as the indicated airspeed increased through 80 KIAS and the pilot attempted to establish 150 KIAS and 8.5 degrees angle of attack. The airspeed stabilized after 12 seconds, but the descent rate, angle of attack, and pitch attitude were not completely stabilized after 20 seconds of flight and the loss of 2500 feet. The rapid stabilator, flaperon, and rudder commands which began at the 13.7 second mark were caused by the spikes mentioned earlier. It is obvious that if these spikes occurred with greater frequency or duration, they could induce significant model responses about all axes which would effect model controllability. It should be noted that the model gyrations which occurred near the end of flights 3-D-2 and 3-D-3 were caused by an intermittent loss of uplink telemetry synchronization and not the spikes generated in the ground control station.

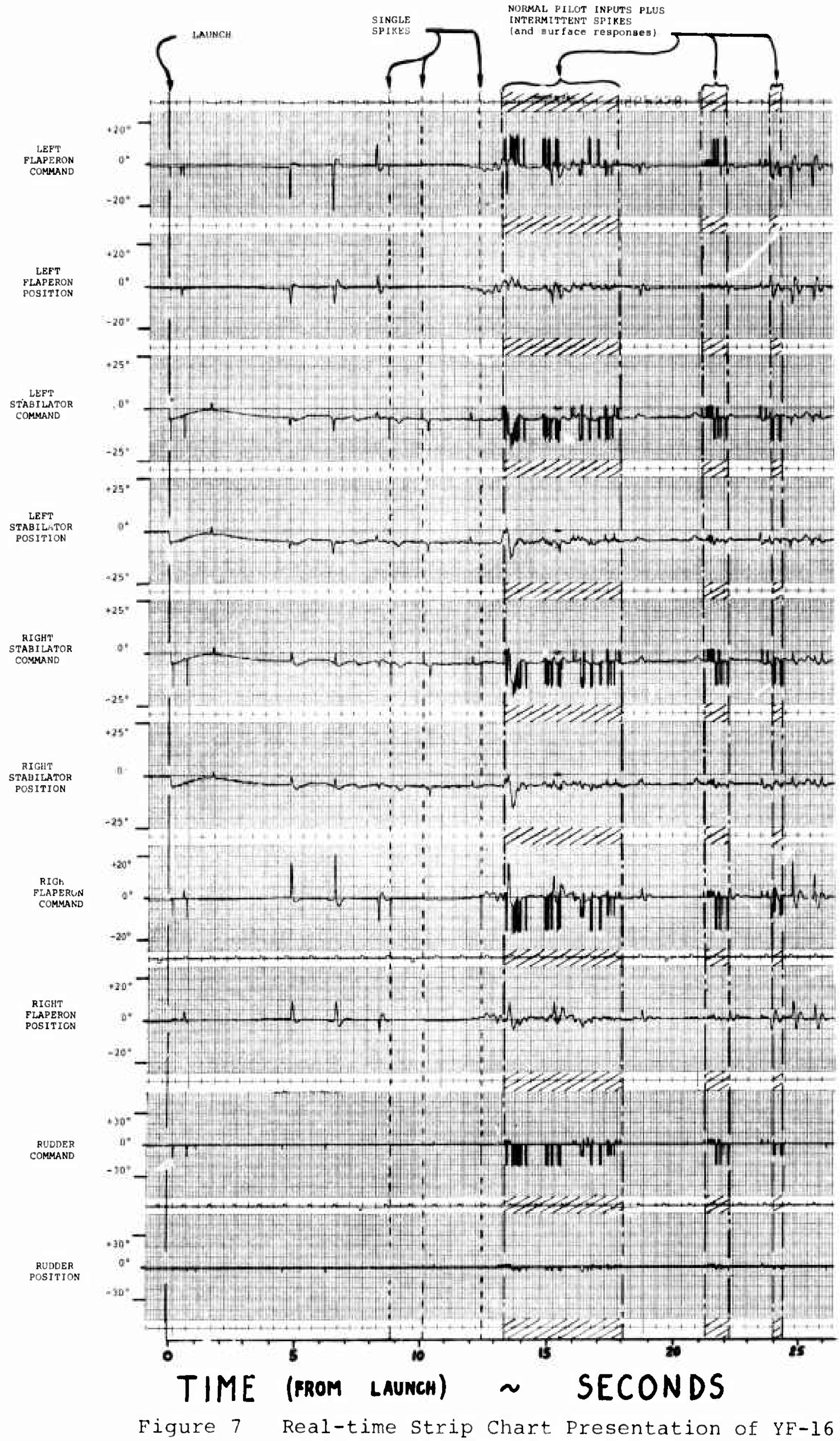


Figure 7 Real-time Strip Chart Presentation of YF-16 Drop Model Surface Commands and Surface Positions

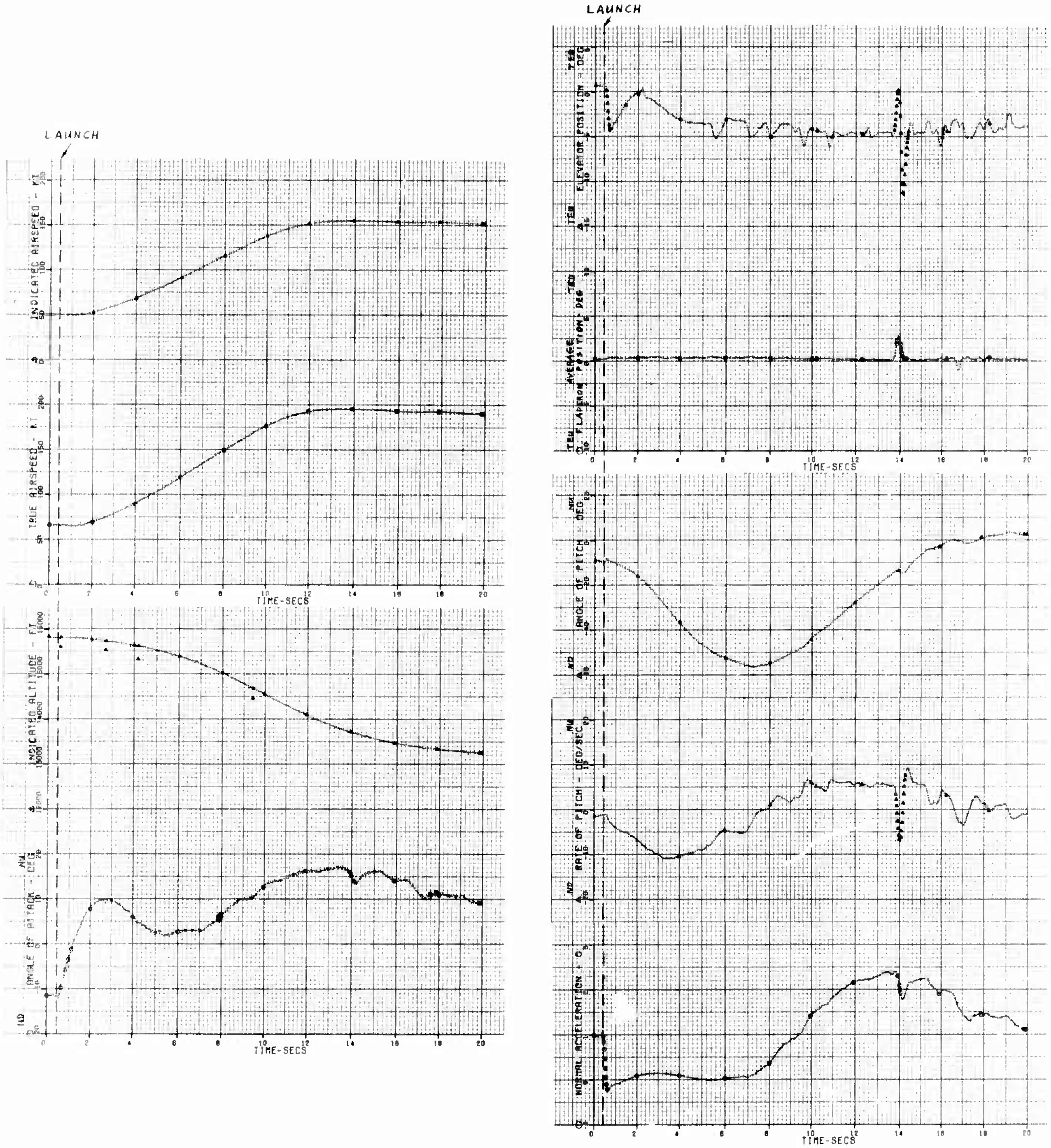


Figure 8 Computer Plotted Time History, Flight 3-D-3 Launch

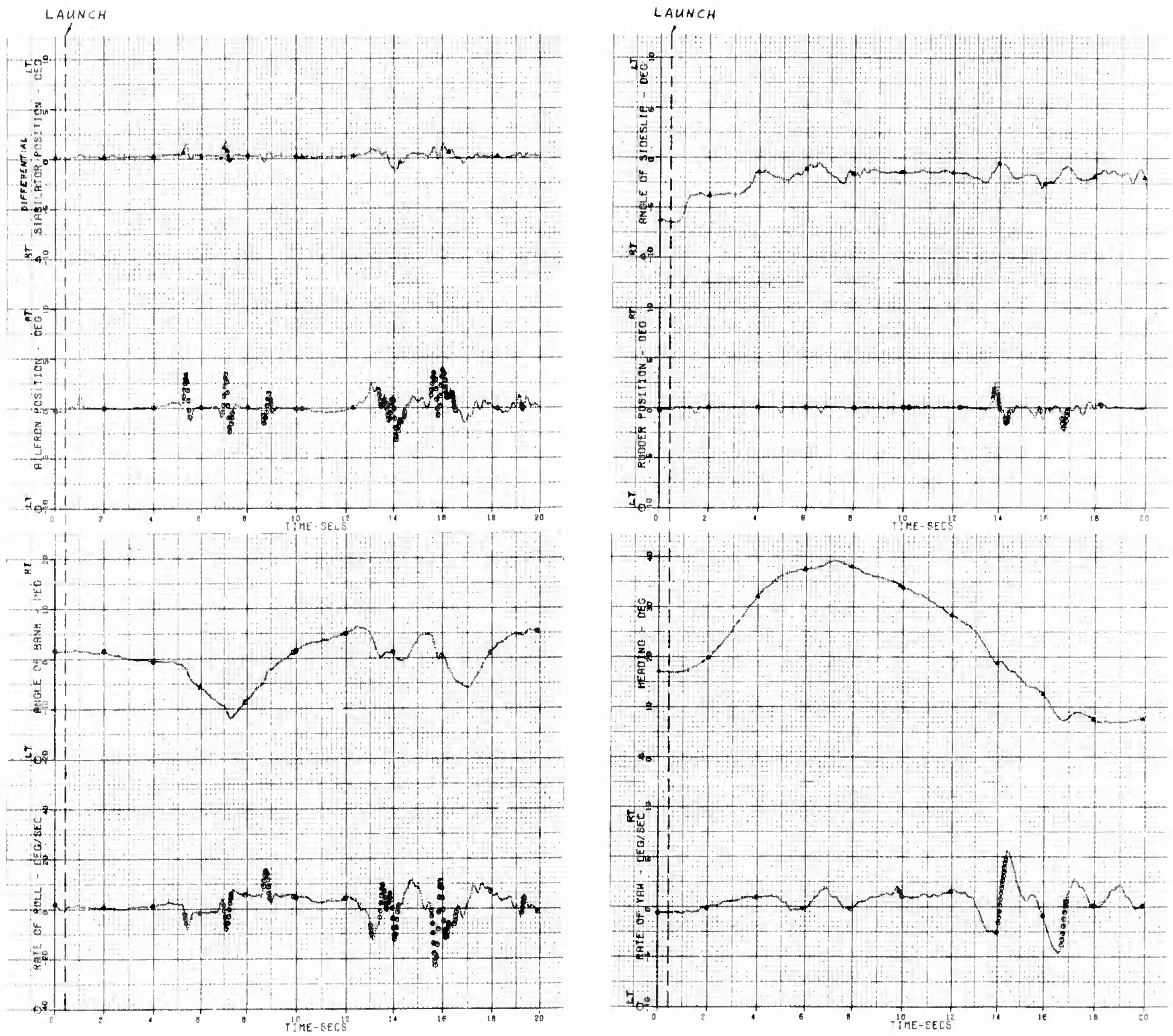


Figure 8 Concluded

Static Longitudinal Stability:

The static longitudinal stability characteristics of the Drop Model are presented in figure 9 as a plot of angle of attack (α) versus elevator position over a Mach number (M) range from 0.20 to 0.28 M. The model exhibited positive static longitudinal stability in that increasing trailing-edge-up elevator deflections were required at increasing angles of attack. Figure 9 also presents the trim curve data for the wind tunnel model at 0.2 M with the cg position at 35 percent mean aerodynamic chord (MAC) and scheduled LEF position[25], and full-scale YF-16 data between 0.28 and 0.48 M with the cg between 34.3 and 35.0 MAC and LEF fixed at 23.75 degrees [26]. The wind tunnel model exhibited neutral stability up to 22 degrees α, and the full-scale YF-16 was unstable up to 23 degrees α.

The shift in trimmed elevator position was most likely caused by the drag of the blocked air intake acting below the model center of gravity producing a nosedown pitching moment. It was also postulated that the blocked air intake disturbed the airflow beneath and around the model fuselage and changed the longitudinal stability characteristics of the model versus the full-scale YF-16 aircraft.

Longitudinal Stability and Control Derivatives:

Stability and control derivatives of the YF-16 Drop Model were determined using test techniques and data reduction methods presented by C. Nagy in AFFTC-TD-75-4[27]. The longitudinal stability and control derivatives were obtained at a trimmed airspeed of 148 KIAS at 8.8 degrees α. The maneuver used to obtain the longitudinal stability and control derivatives consisted of a rapid pitch doublet followed by the Drop Model response. The derivatives were extracted using the Modified Maximum Likelihood Estimation (MMLE) computer program described in reference 3. A time history of this pitch maneuver is presented in figure 10. Figures 11 to 13 contain the longitudinal derivatives obtained from the Drop Model, the wind tunnel, and the full-scale YF-16.

The derivatives extracted from this one maneuver compare favorably with the wind tunnel model and full-scale YF-16 derivatives except the change in pitching moment coefficient due to change in angle of attack,

[25] The full-scale YF-16 leading edge flaps were scheduled with angle of attack and Mach number, and consequently the wind tunnel data was presented in that manner.

[26] The full-scale YF-16 flew several 1-g decelerations with the leading edge flaps fixed at different deflections. This data was acquired from such decelerations with LEF fixed at 23.75 degrees.

[27] Reference 3: Nagy, Christopher J., A New Method for Test and Analysis of Dynamic Stability and Control, AFFTC-TD-75-4, Air Force Flight Test Center, Edwards AFB, California, May 1976.

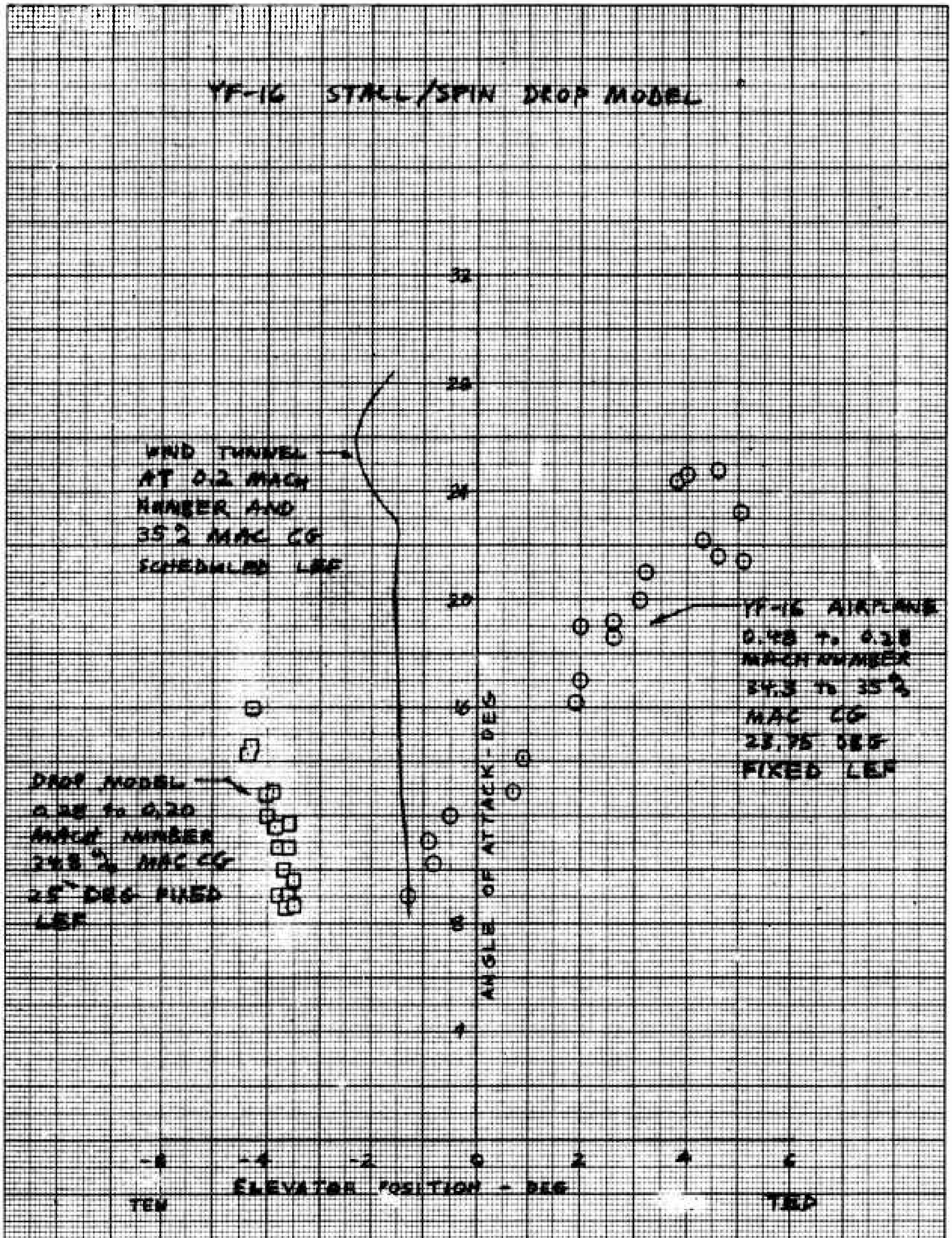


FIGURE 9 ELEVATOR TRIM COMPARISON

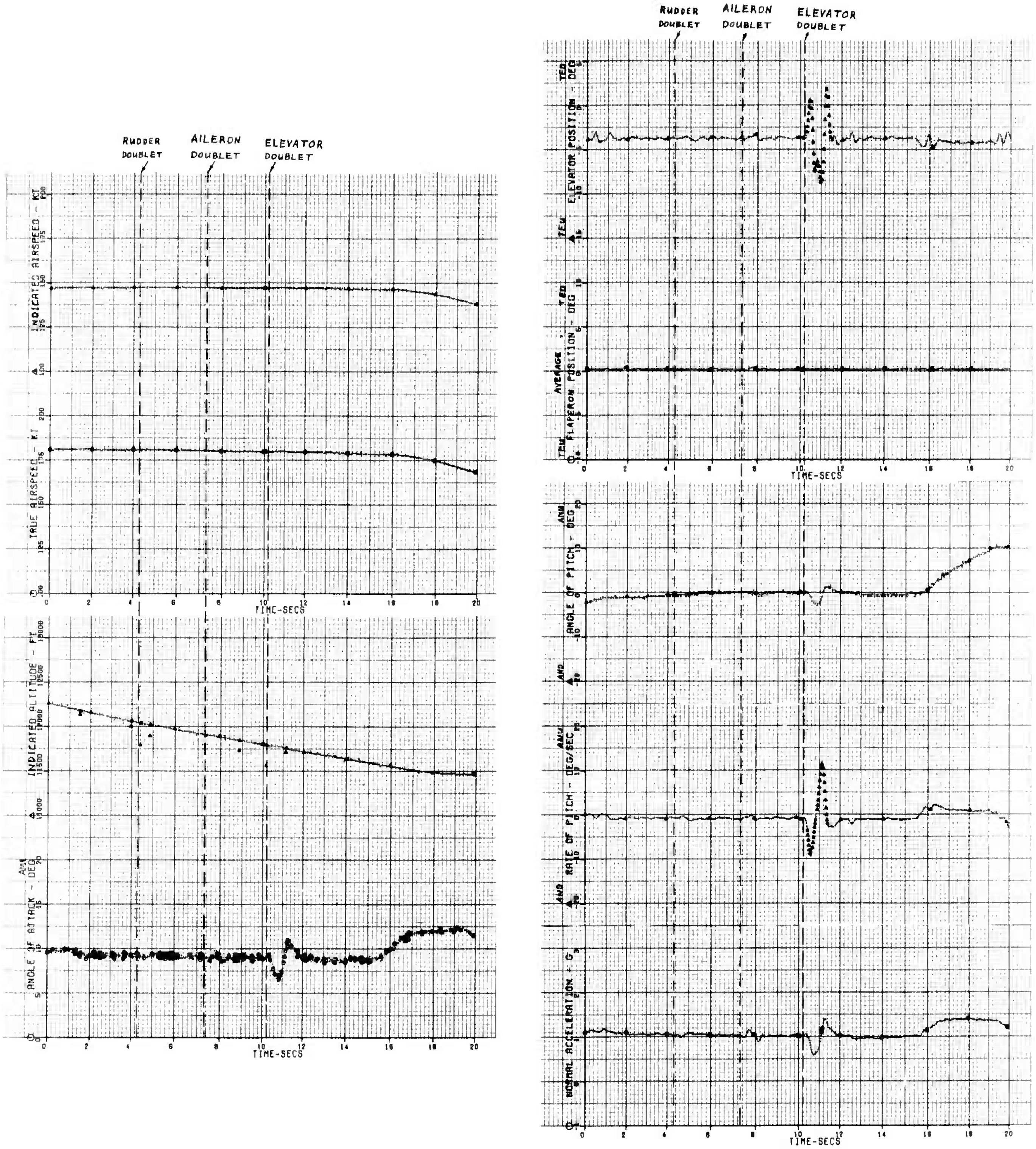


Figure 10 Computer Plotted Time History, Flight 3-D-3 Stability and Control Maneuver

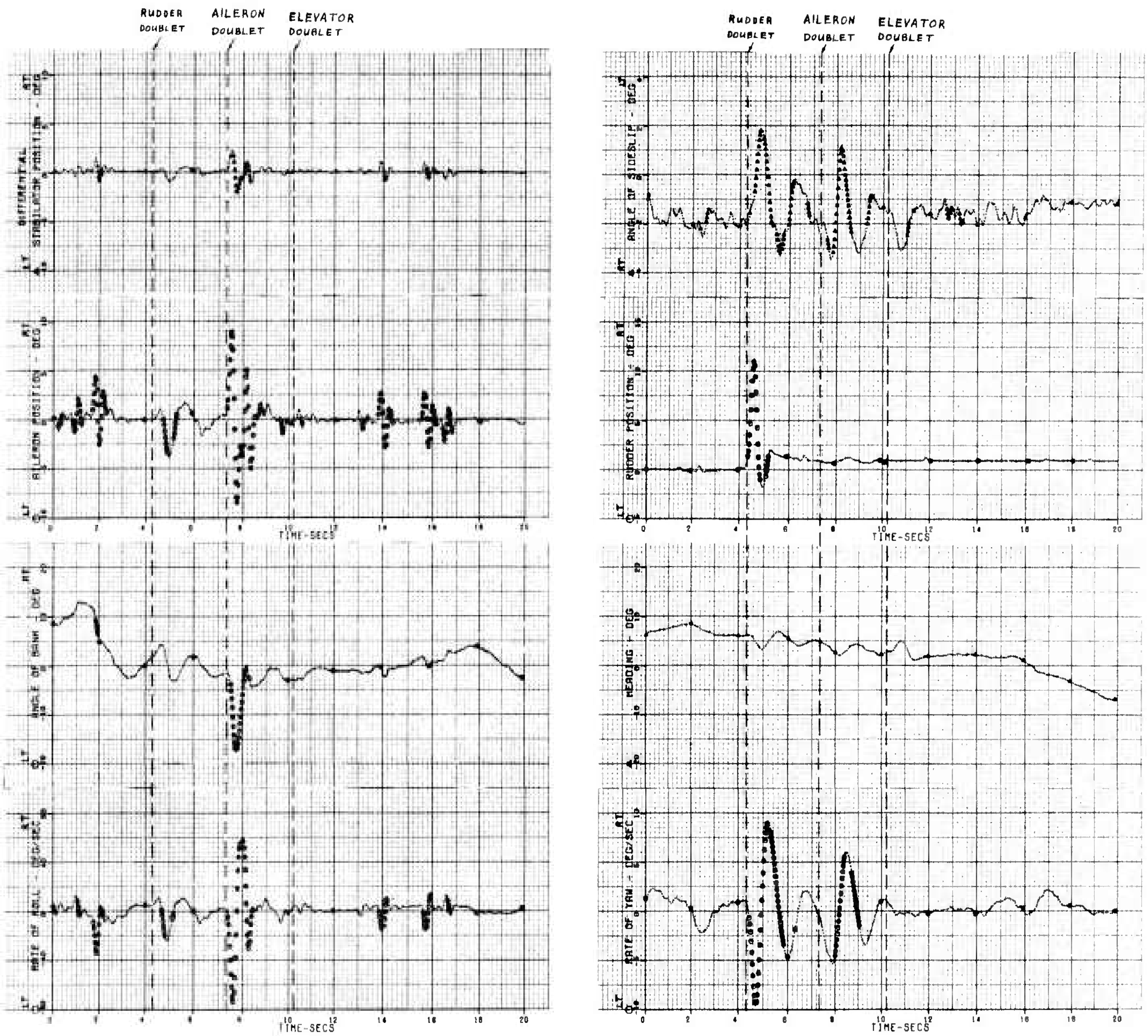


Figure 10 Concluded

C_{m_α}, (figure 11). The slightly negative C_{m_α} obtained from this dynamic maneuver supports the conclusion derived from the α versus δe curve, that the Drop Model exhibited positive static longitudinal stability.

The change in normal force coefficient due to a change in elevator position, $C_{N_{\delta_e}}$ is presented in figure 12. $C_{N_{\delta_e}}$ for the Drop Model compares closely with the wind tunnel model and the full-scale YF-16 data. The change in pitching moment coefficient due to a change in elevator position, $C_{m_{\delta_e}}$ is presented in figure 12. The Drop Model again compared closely with the wind tunnel model and full-scale YF-16 data. The change in normal force coefficient due to a change in angle of attack, C_{N_α}, is also presented in figure 12. Again the Drop Model compared closely with the C_{N_α} trend in wind tunnel and full-scale YF-16 data.

The change in pitching moment coefficient due to pitch rate, C_{m_q} is presented in figure 13. C_{m_q} compares closely with wind tunnel model and full-scale YF-16 data.

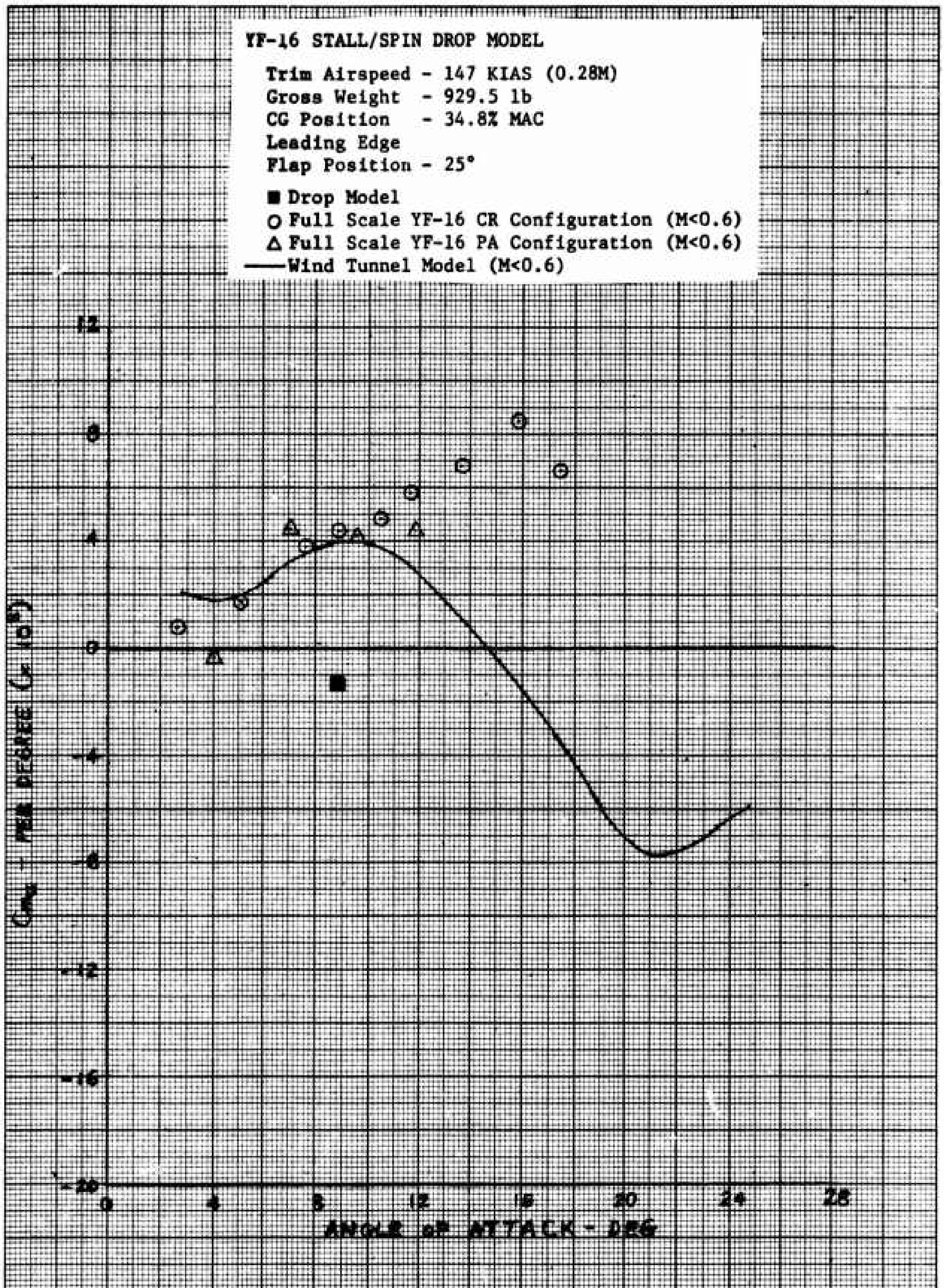


FIGURE 11 - LONGITUDINAL DERIVATIVES

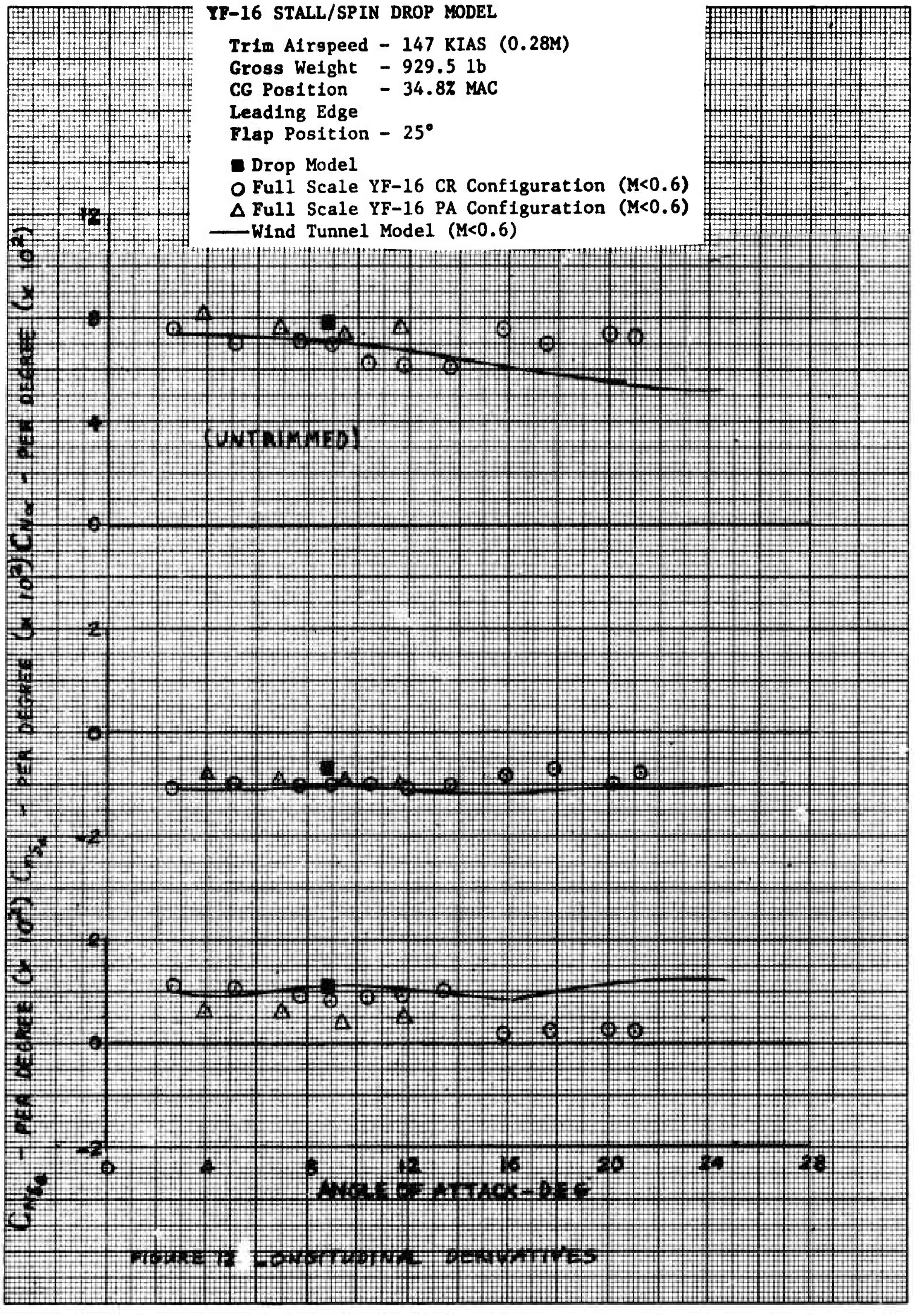


FIGURE 12 LONGITUDINAL DERIVATIVES

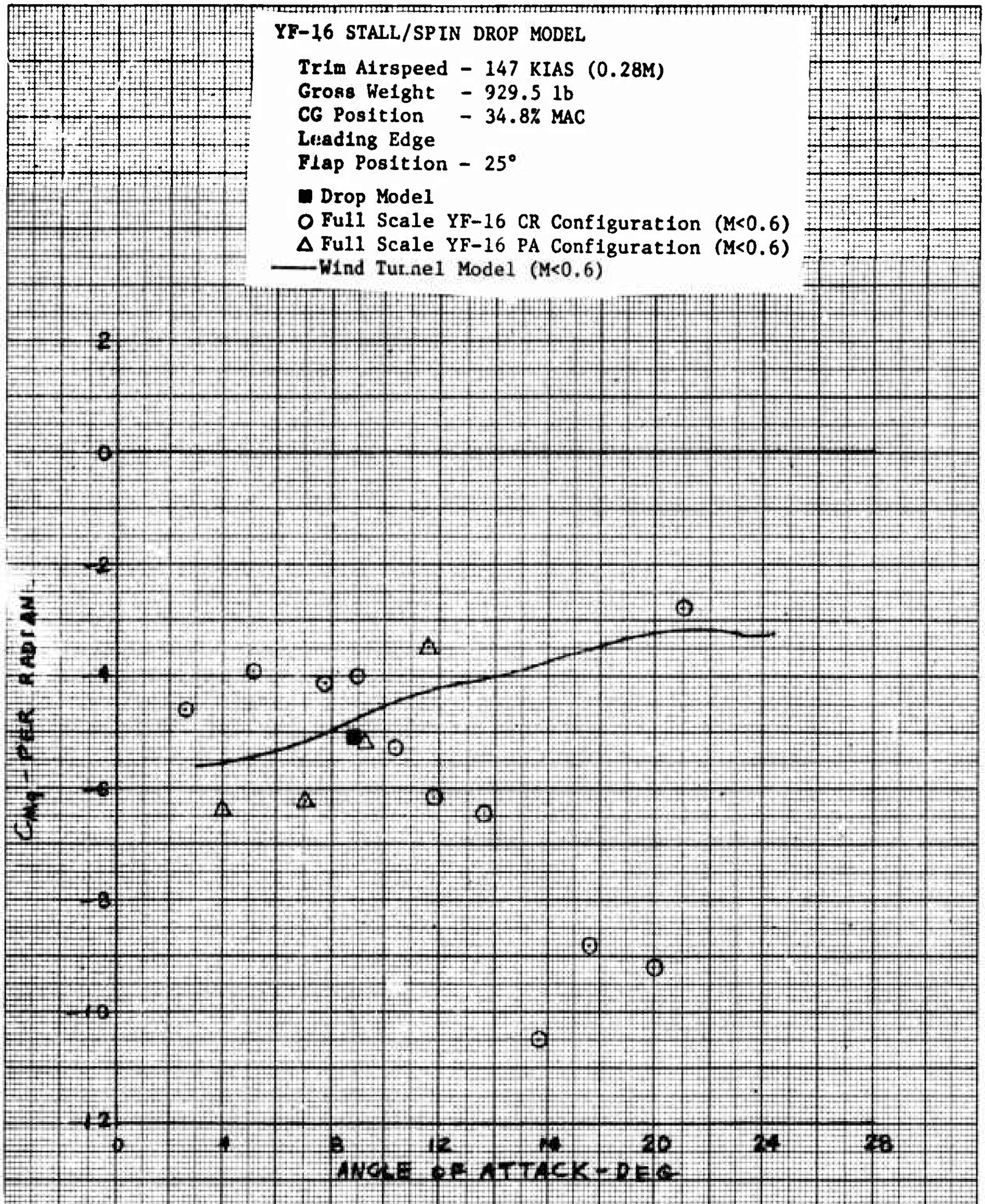


FIGURE 13. LONGITUDINAL DAMPING DERIVATIVES

Lateral-Directional Stability and Control Derivatives:

The lateral-directional stability derivatives were obtained using the test techniques and extraction techniques of the MMLE program contained in reference 3. The trim conditions were 148 KIAS and 9.0 degrees α. The maneuver used to obtain the derivatives was a rudder doublet followed by an aileron doublet. A time history of this maneuver and the resultant response is also presented in figure 10. As with the longitudinal derivatives, the lateral-directional derivatives of the Drop Model compared favorably with wind tunnel model and the full-scale YF-16 results.

Figure 14 contains a plot of the change in yawing moment due to sideslip, C_{n_β}, versus angle of attack. C_{n_β} is a measure of the tendency of the Drop Model to align with the relative wind. The Drop Model data point lies very close to the wind tunnel data, and shows increased stability over the full-scale YF-16.

The diherdral effect or change in rolling moment due to sideslip, C_{ℓ_β}, versus angle of attack is presented in figure 15. The dihedral effect of the Drop Model appeared slightly stronger than the wind tunnel model and full-scale YF-16.

The side force derivative due to sideslip, C_{y_β}, versus angle of attack is presented in figure 16. C_{y_β} appears weaker than the wind tunnel model or the full-scale YF-16.

The lateral-directional control derivatives, $C_{n_{\delta_r}}$, $C_{\ell_{\delta_r}}$, $C_{n_{\delta_\alpha}}$, and $C_{\ell_{\delta_\alpha}}$, are presented versus angle of attack in figures 17 and 18. $C_{\ell_{\delta_\alpha}}$ was 25 percent greater for the Drop Model than for the full-scale YF-16; the other control derivatives compared closely with full-scale YF-16 data.

The lateral-directional damping derivatives are presented in figures 19 and 20. The Drop Model yaw damping derivatives, C_{n_r} and C_{ℓ_r}, compare favorably with wind tunnel and full-scale YF-16 derivatives. The roll damping derivative, C_{ℓ_p}, also compares favorably, but the Drop Model yaw due to roll rate, C_{n_p}, is considerably greater than wind tunnel and full-scale YF-16 data.

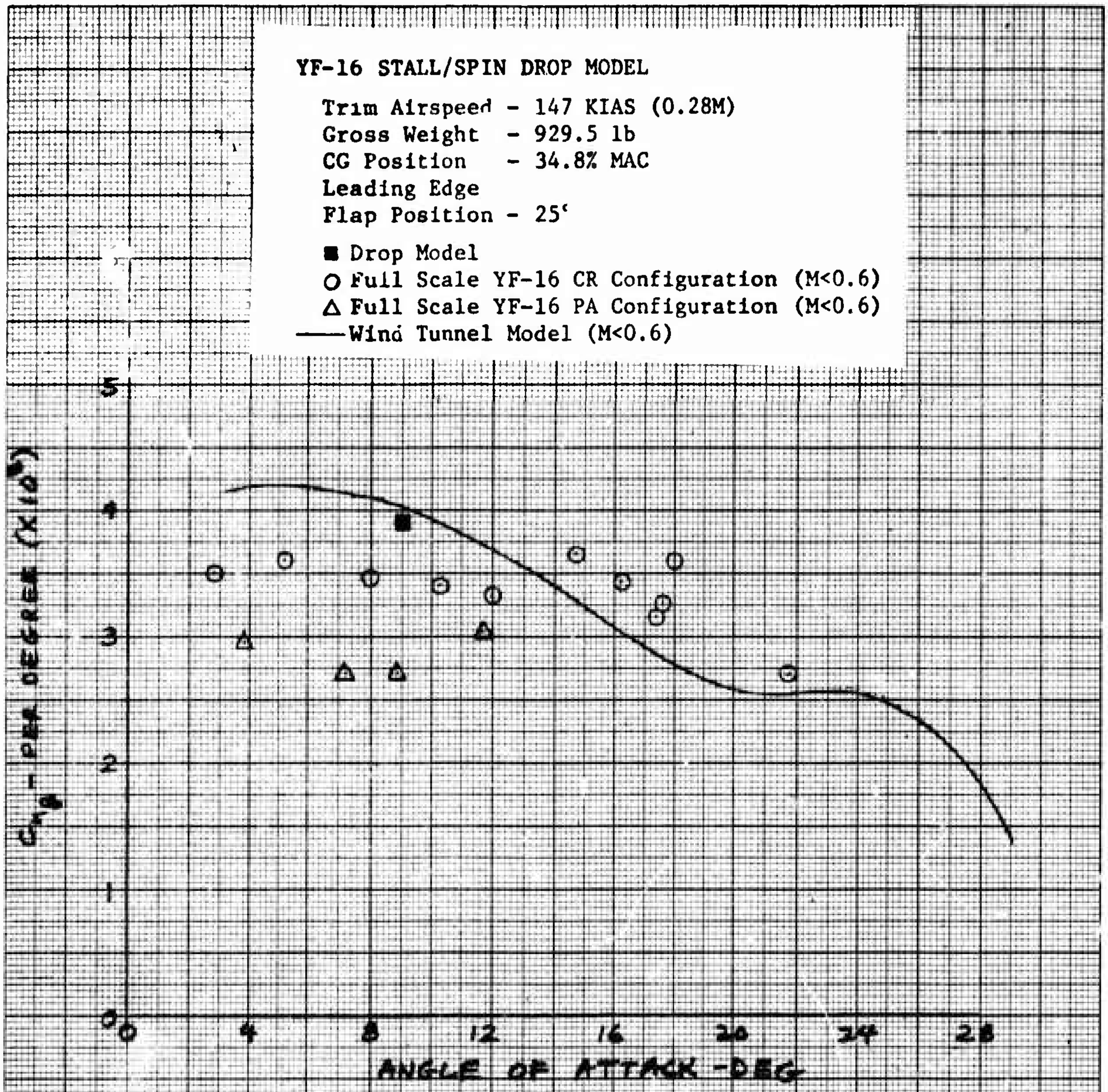


FIGURE 14 SIDESLIP DERIVATIVES

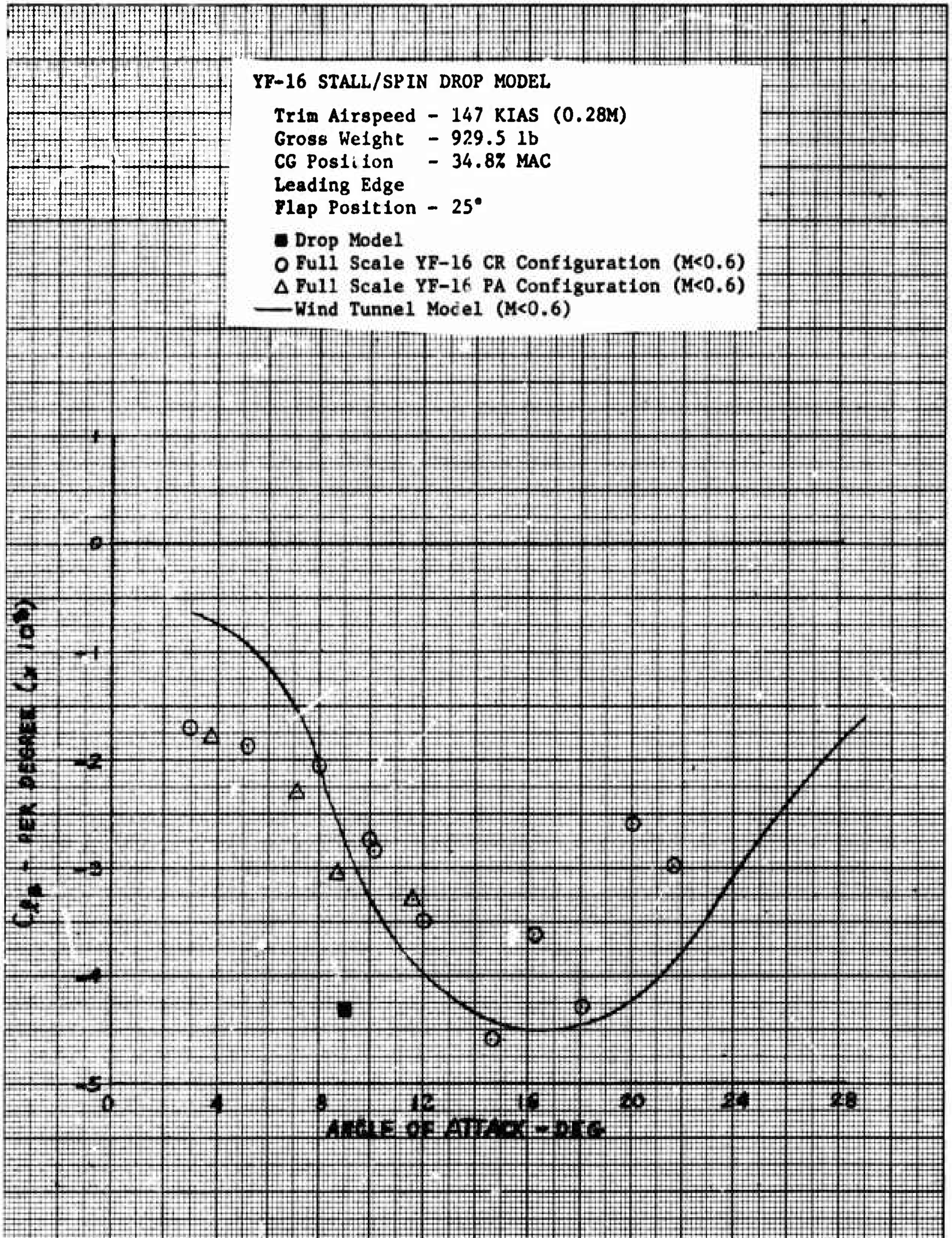


FIGURE 15 - SIDESLIP DERIVATIVES

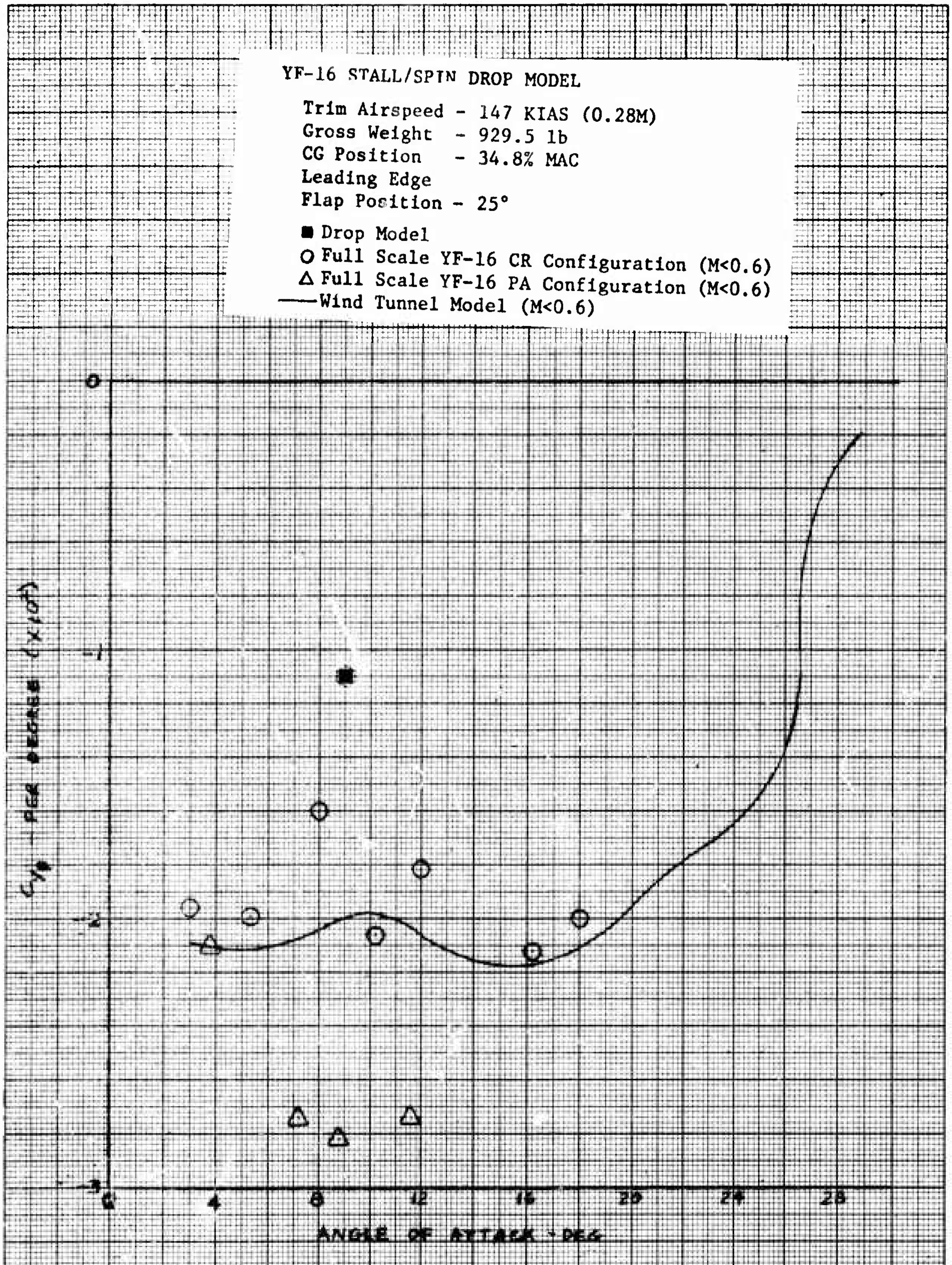


FIGURE [illegible] SIDESLIP DERIVATIVES

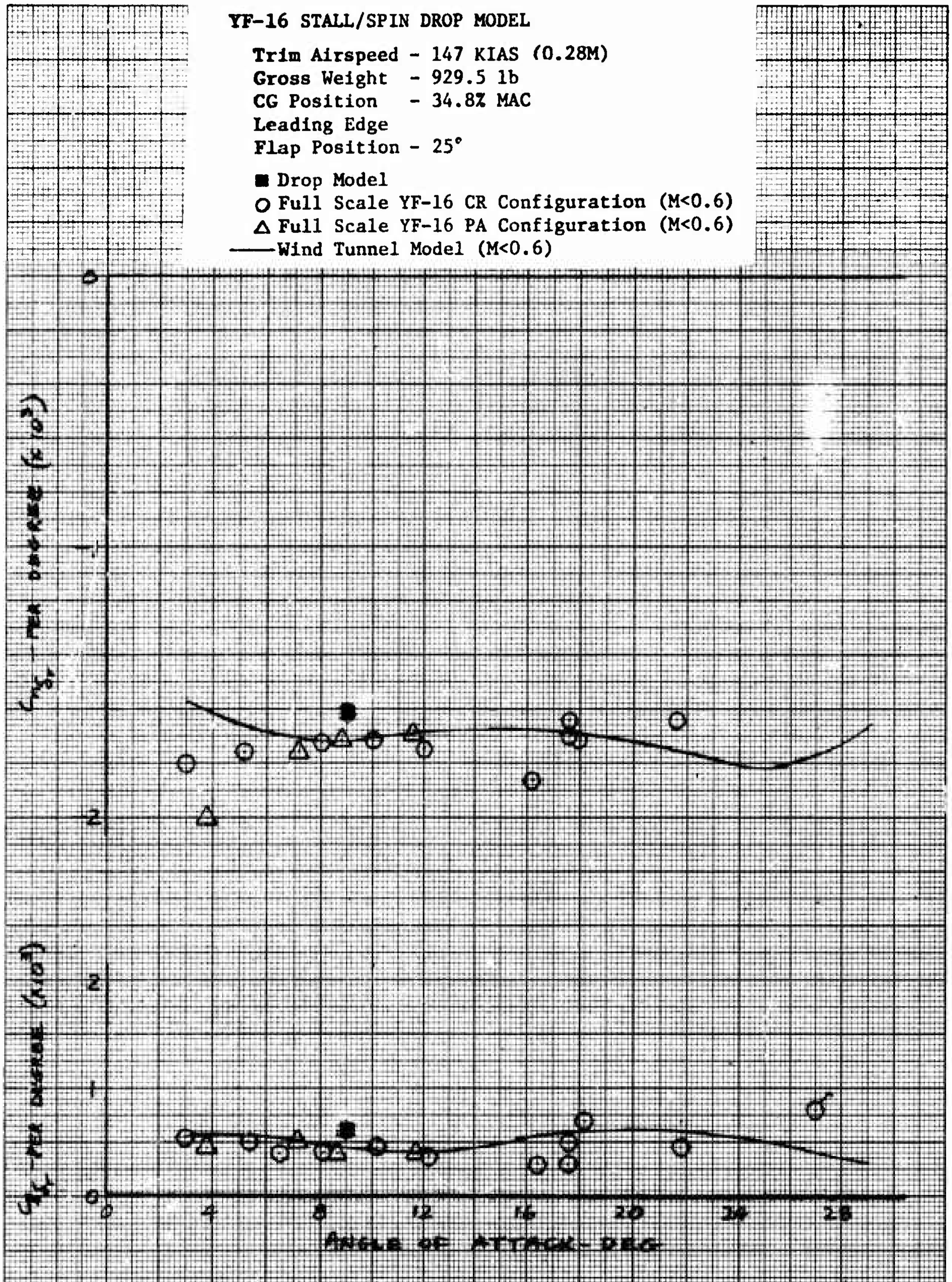


FIGURE 17 RUDDER DERIVATIVES

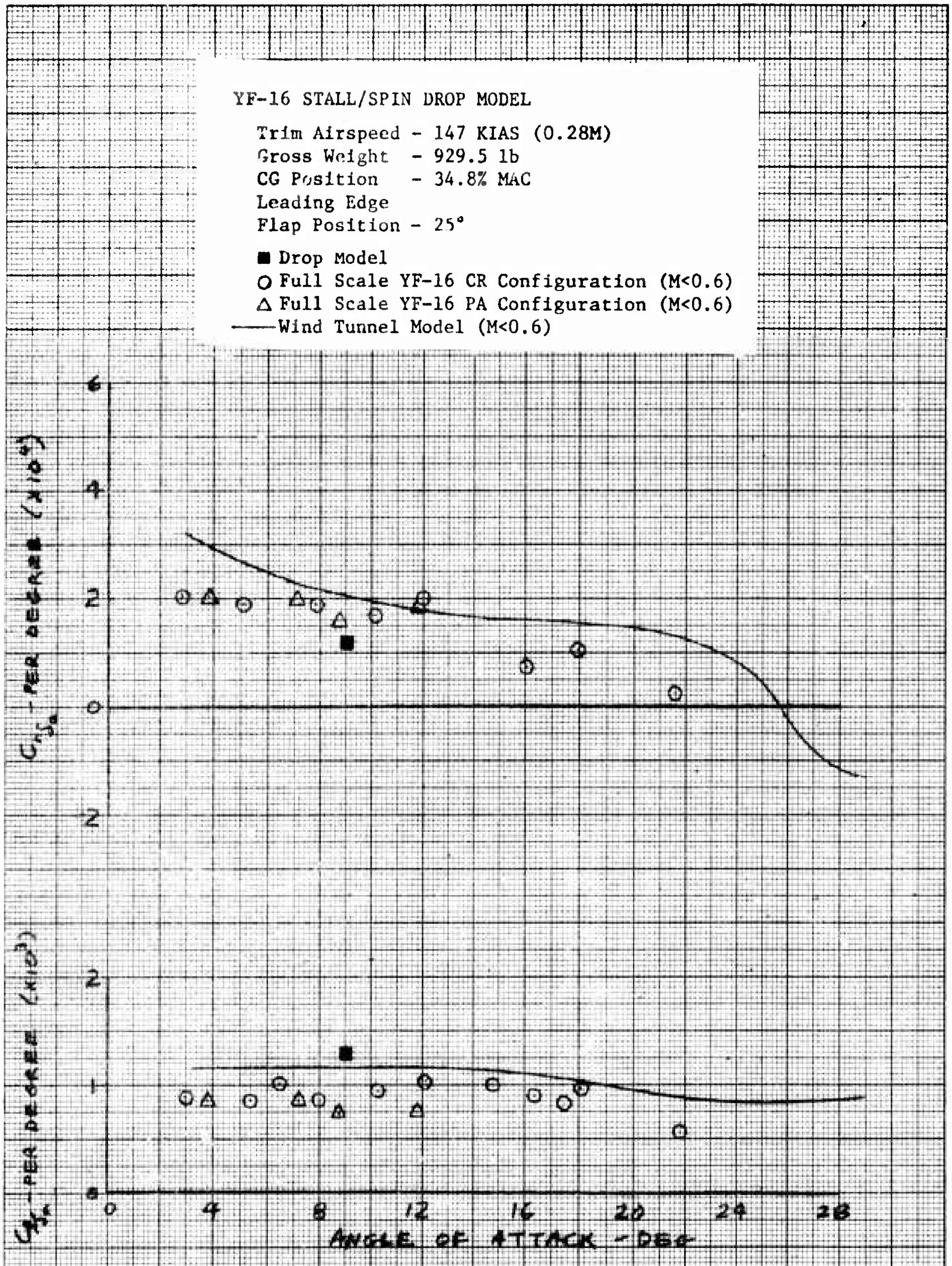


FIGURE 18 LATERAL CONTROL DERIVATIVES

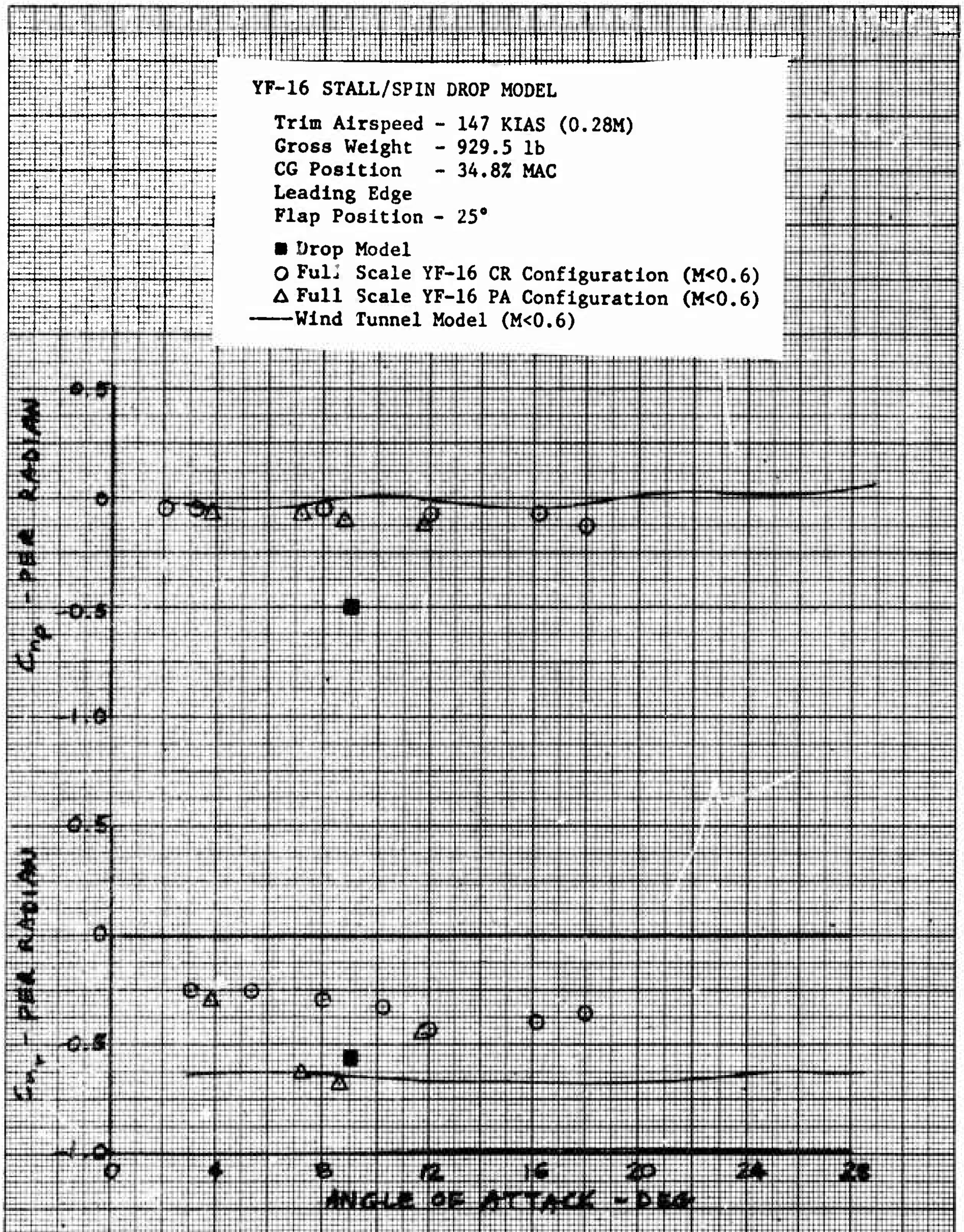


FIGURE 19 LATERAL-DIRECTIONAL DAMPING DERIVATIVES

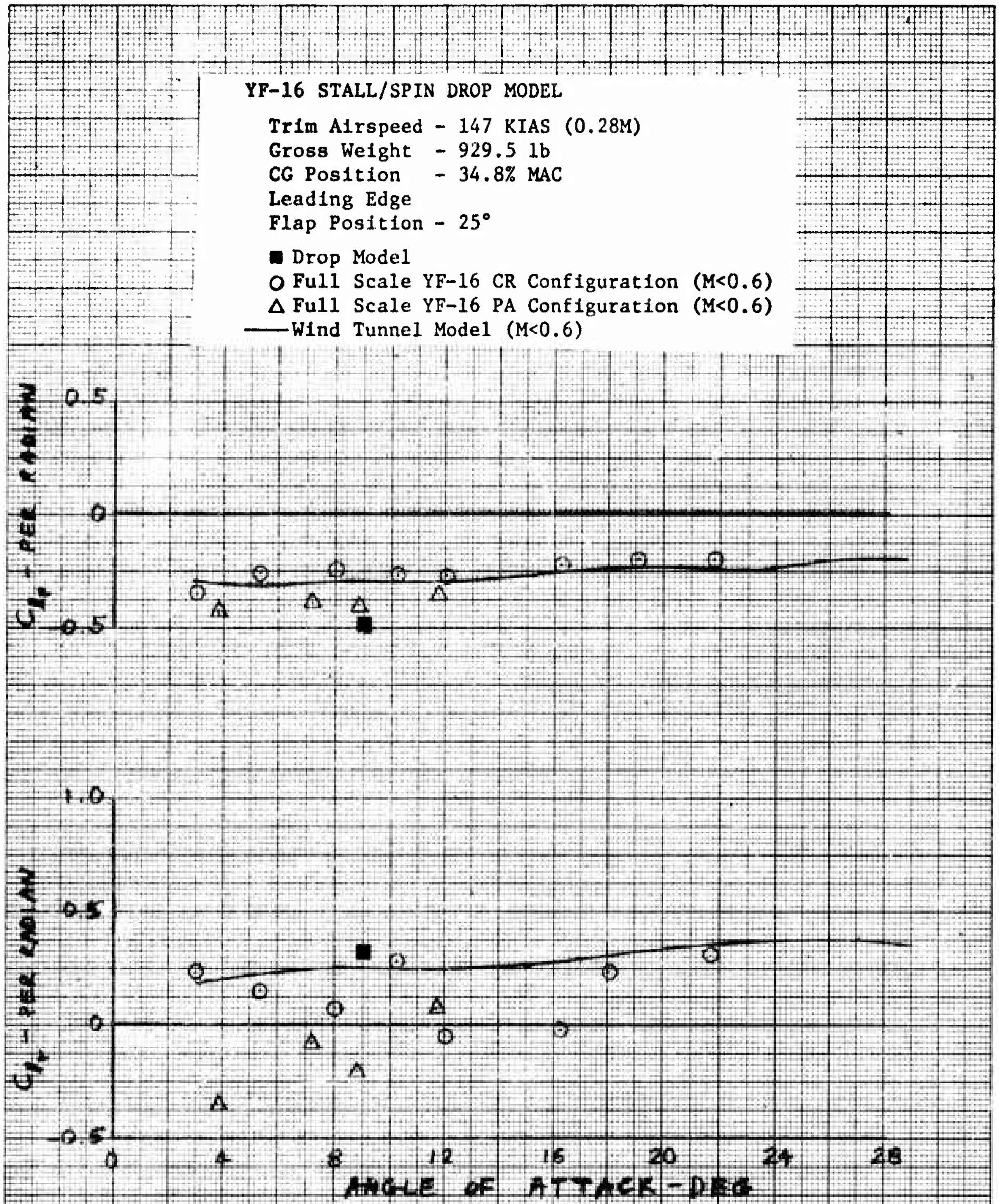


FIGURE 20 LATERAL-DIRECTIONAL DAMPING DERIVATIVES

Performance Data Reduction Techniques:

Normal force coefficient, (C_N), chord force coefficient, (C_C), lift coefficient, (C_L), and drag coefficient, (C_D), were determined from constant airspeed turns and descents. Normal force coefficient was calculated from:

$$C_N = \frac{n_z}{\bar{q}} \times \frac{W}{S}$$

where

n_z = normal load factor, nondimensional

$\bar{q}$ = dynamic pressure, psf

W = gross weight, lb

S = wing area, ft^2

The chord force coefficient could be determined from:

$$C_C = \frac{n_x}{\bar{q}} \times \frac{W}{S}$$

where

n_x = longitudinal load factor, nondimensional

However, the longitudinal accelerometer was scaled improperly (-2.5 to 0.0 g) and could not be used to calculate chord force. Therefore, C_C, C_L, and C_D were calculated from constant airspeed turns and descents using a one-step iterative process. Brief periods of extremely stable flight were identified and an average descent rate was determined from a plot of altitude versus time. Average true airspeed during the time increment was used to obtain a descent angle from:

$$\gamma = \sin^{-1} \frac{dh/dt}{V_t}$$

where

γ = descent angle, deg

dh/dt = descent rate, fps

V_t = average true airspeed, fps

First estimates (the superscript ($'$) indicates an estimated value) for the iterative process were then calculated from:

$$C_L' = C_N \cos \alpha$$

$$C_D' = C_L' \tan \gamma \cos \phi_a$$

$$C_C' = C_D' \cos \alpha - C_L' \sin \alpha$$

where

α = angle of attack, deg

ϕ_a = average bank angle during maneuver, deg

The original C_N and the C_c' determined above were then used to obtain the new C_L and C_D values:

$$C_L = C_N \cos \alpha - C_c' \sin \alpha$$

$$C_D = C_N \sin \alpha + C_c' \cos \alpha$$

Comparison of C_L and C_D with C_L' and C_D', respectively, revealed that differences were less than 0.6 percent in all cases, and further iterations were not necessary.

Performance:

The normal force coefficient (C_N) versus angle of attack relationship was determined from flight test data and is presented in figure 21 with a C_N versus α curve from full-scale YF-16 flight tests. C_N for the Drop Model was 0.10 to 0.13 less than the full-scale airplane. Figure 22 contains a plot of lift coefficient (C_L) versus angle of attack data for the Drop Model and a curve derived from flight tests of the full-scale YF-16. The Drop Model lift coefficient was generally 0.1 to 0.15 less than the full-scale YF-16 values over the angle of attack range tested. Figure 23 presents drag coefficient (C_D) plotted versus C_L for the Drop Model and the full-scale airplane. The Drop Model showed 0.030 to 0.070 greater drag coefficient than the full-scale YF-16 throughout the range of C_L tested. It is felt that the blocked air intake on the Drop Model was the prime source of increased drag. The increased trim drag caused by the shift in the trim curve (figure 9) was contributing factor. The decreased lift coefficient (up to 30 percent) and greatly increased drag coefficient (over 200 percent) caluclated for the Drop Model were confirmed by the diminished glide performance experienced in flight versus that predicted by the simulation.

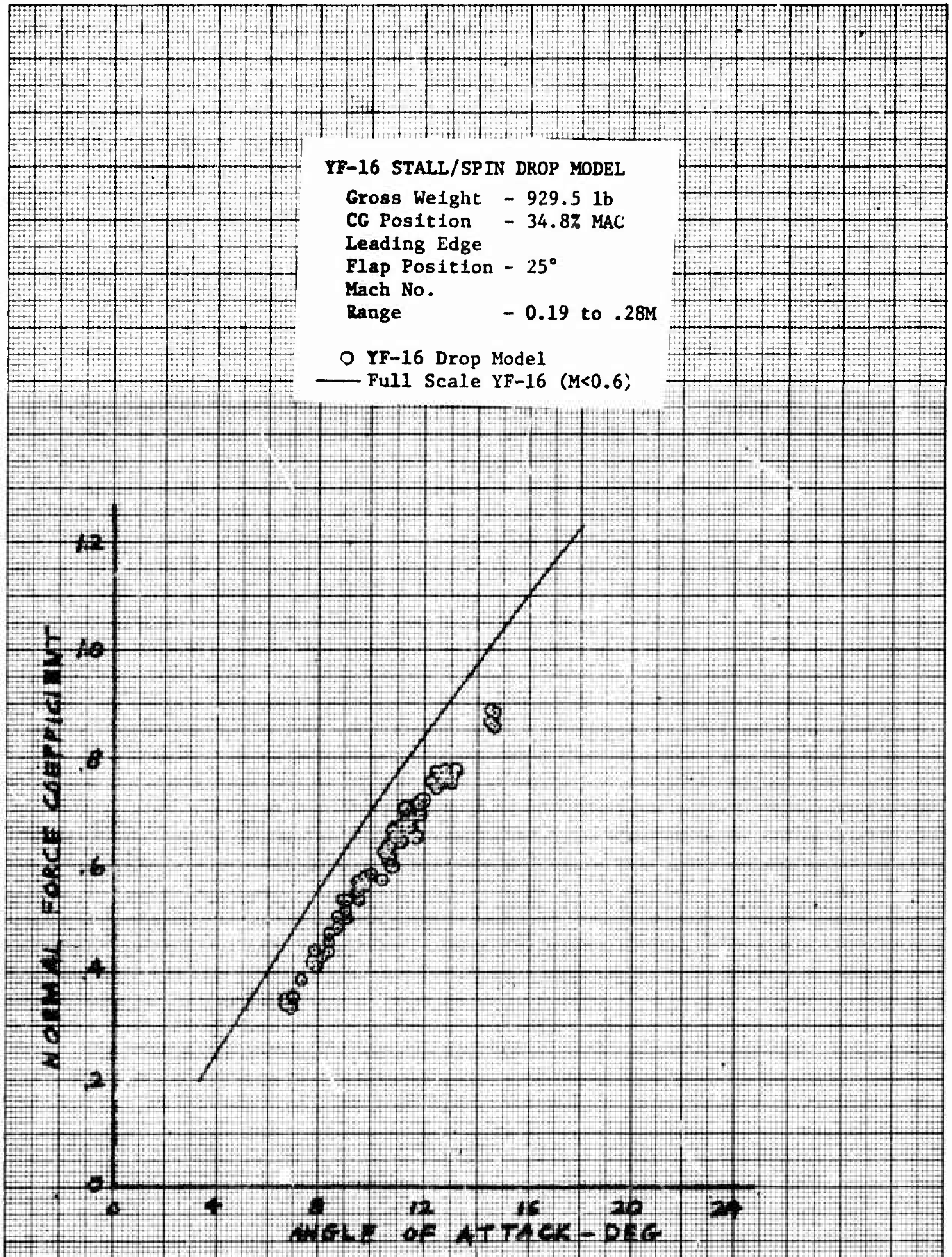


FIGURE 3: NORMAL FORCE COEFFICIENT CHARACTERISTICS

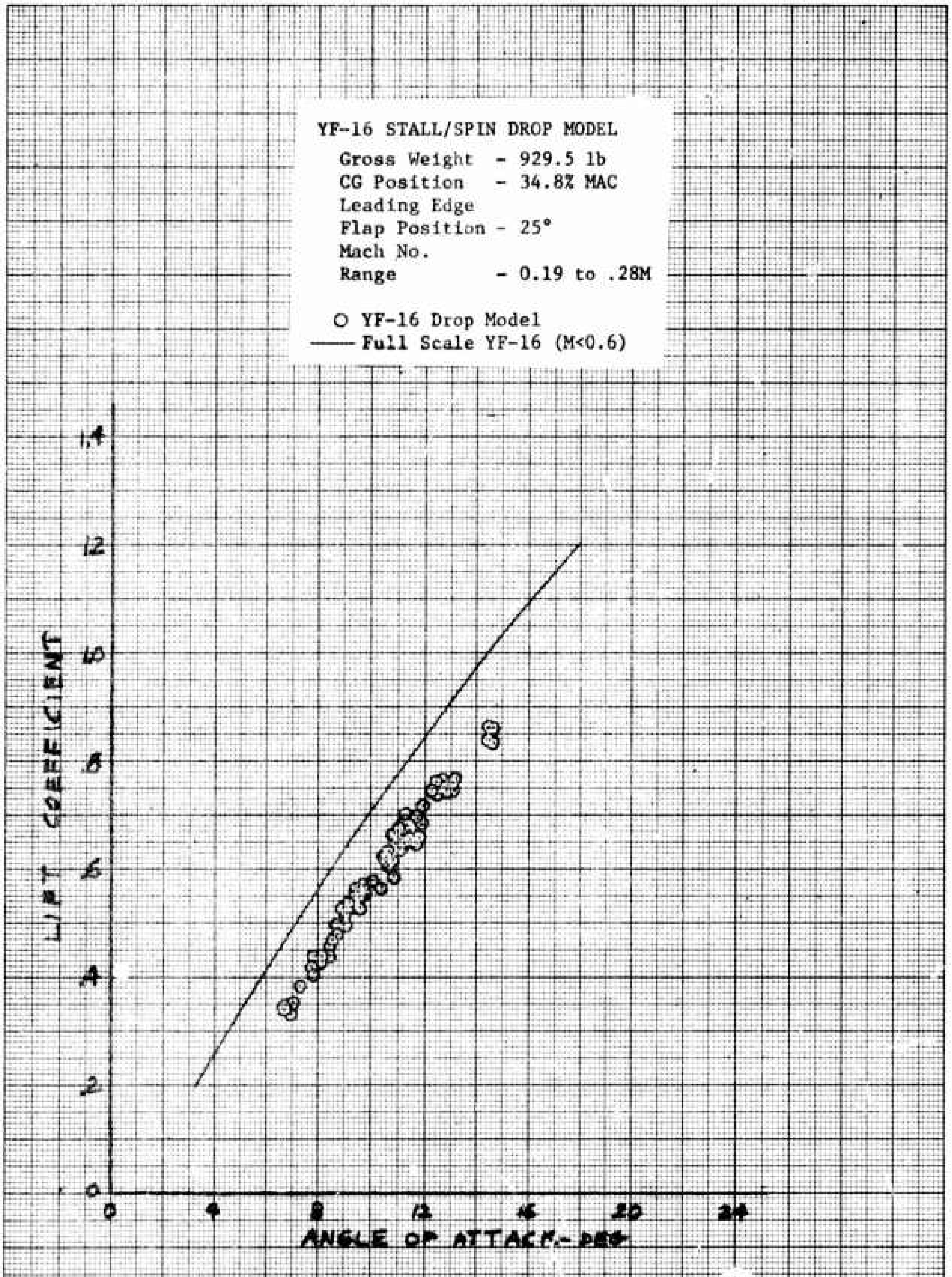


FIGURE 22 LIFT COEFFICIENT CHARACTERISTICS

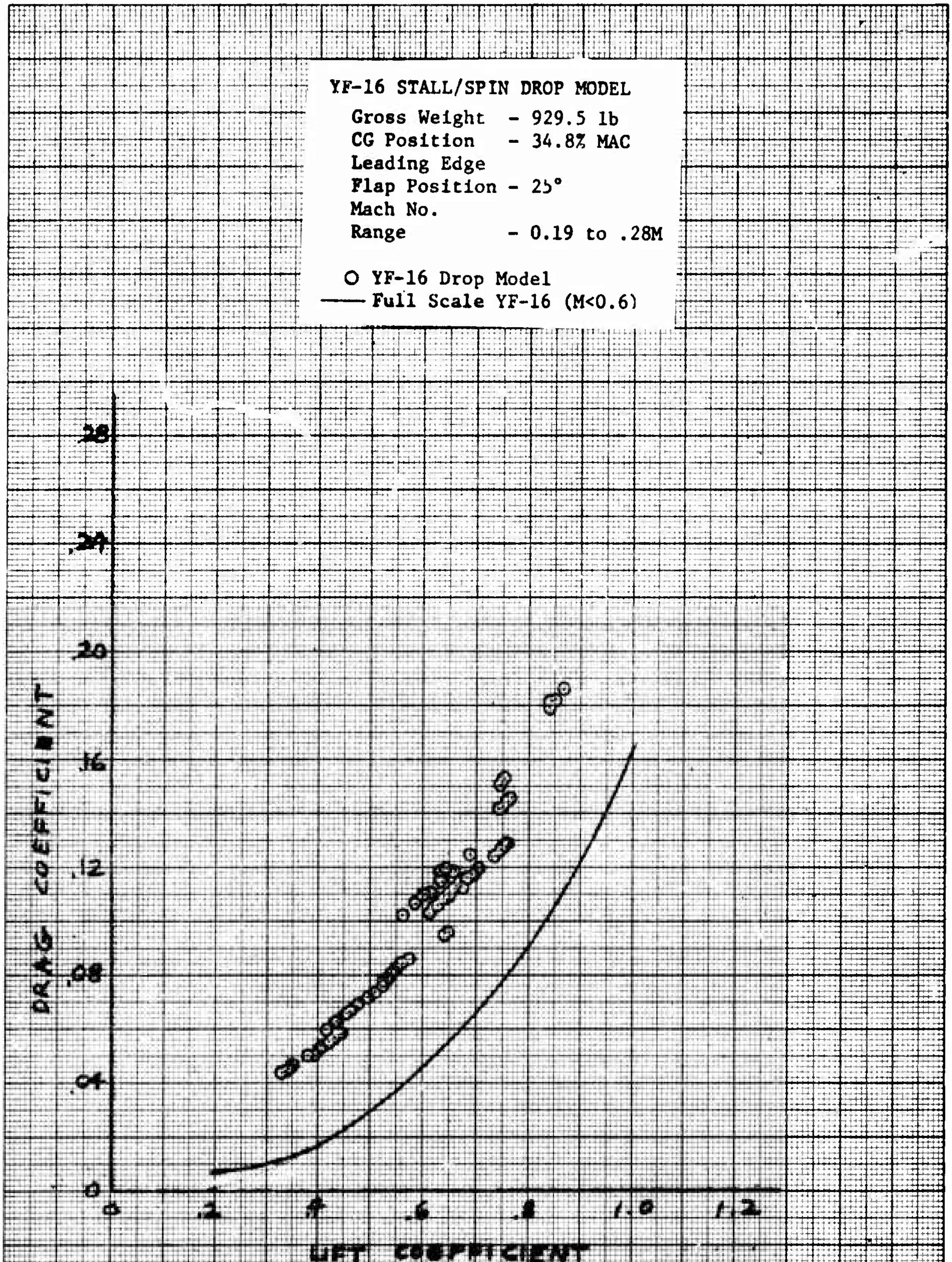


FIGURE [illegible] DRAG CHARACTERISTICS

CONCLUSIONS AND RECOMMENDATIONS

GENERAL

Sufficient flight testing was accomplished to demonstrate the feasibility of conducting a Remotely Piloted Research Vehicle program with extremely limited resources using the equipment provided by the Air Force Dynamics Laboratory (AFFDL). When all system components operated properly, the quality of the data acquired was sufficient for real-time control of the model and for postflight data analysis. Delays caused by extremely unreliable system components and the inordinate time required to repair structural damage sustained by the model during parachute landings caused excessive turn-around times between flights. These delays diminished the frequency of model flights to the point that the small amount of data acquired did not justify the expenditure of resources required.

The original program objectives established by the AFFDL were not accomplished. Verification of the validity of drop model testing by comparing stability and control derivatives of the model with those of the full-scale airplane was the only objective addressed. Model derivatives were obtained at only one trim condition, and although most derivatives compared favorably, there were significant differences in pitching moment that resulted in different stabilator trim characteristics. In addition, the Drop Model exhibited a significant decrease in gliding performance due to lower lift and higher drag compared to the full-scale YF-16. Based on the reported success of the National Aeronautics and Space Administration/Dryden Flight Research Center F-15 Drop Model Program[28] in acquiring high angle of attack data, and the demonstrated capability to conduct flight test operations with the YF-16 Drop Model, it is concluded that accomplishment of the original AFFDL objectives is feasible (provided that the specific CRITICAL deficiencies listed below are remedied).

Before discussing the deficiencies, it should be noted that certain systems and components were particularly well suited for the Drop Model Program. The electrohydraulic servoactuators and the servocontroller performed flawlessly during the program and provided excellent control surface response; the hydraulic motor/pump assembly operated well. The C-band radar transponder provided a strong radar target for all model flight operations. The concept and the operation of the noselift mechanism were highly beneficial; the hinge failed on the second landing, but subsequent strengthening modifications withstood a touchdown in an unusual nosedown attitude on the third flight and nose boom damage was prevented. The airborne encoder and decoder units and the ground-based decoder all operated properly throughout the program. In the ground control station, the minicomputer operated without failure. With the exception of an inadvertent separation of the umbilical cable at the quick-disconnect on the second flight, the operation of the launch-rack mechanism and the helicopter Class II modification equipment was excellent. Other systems not specifically mentioned in these conclusions operated adequately.

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[28]Reference 4: Layton, Garrison P., "A New Experimental Flight Research Technique: The Remotely Piloted Airplane", Agard Conference Proceedings No. 187, April 1976, Hartford House, London, UK.

The rest of this section will be devoted to presenting the early management decisions which eventually led to the hardware deficiencies encountered during the program and which ultimately caused the termination of the program. This discussion is intended to point out some of the pitfalls which may plague any research flight test program in which procurement of an entirely new flight test vehicle or system is involved. The general effects of these decisions on the quality of the hardware and software provided by the contractor and modified by the Air Force Flight Test Center (AFFTC) test team will be discussed. Though the Drop Model project has been terminated, and will probably not be regenerated, specific hardware deficiencies will be presented and recommendations for correcting these deficiencies will be offered. Some specific deficiencies were determined to be CRITICAL and must be corrected in the unlikely event that any flight test operation was resumed using this equipment. Other deficiencies were determined to be NONCRITICAL and could be corrected as time and resources permit to improve overall project results.

The contractor selected to build the Drop Model System and to conduct the flight test program provided equipment that did not exhibit the overall reliability necessary to conduct a safe and effective flight test operation. The system checkout procedures, the operational flight procedures, and the concepts of command and control originally proposed by the contractor for the test flights were inadequate. The component checkout procedures and the instrumentation calibration procedures established by the contractor indicated that he had an insufficient understanding of the accuracy, stability, and reliability of the data (and hence the data sensors) required to accomplish the AFFDL program objectives. Consequently, the accuracy and reliability of many system components were inadequate, and failures caused repeated delays throughout the program.

The YF-16 Drop Model System (the ground control station and the models) was delivered to the AFFTC while still under development. No interaction of the major system components had been attempted prior to delivery and, in fact, the ground control station was not capable of such interaction. The contractor intended to complete the system development work at the AFFTC before beginning flight test operations. This created additional problems in that the equipment, facilities, and expertise available at his home facility were unavailable at the AFFTC, consequently his progress was severely impeded. In supporting these contractor development efforts, Air Force test and evaluation resources were expended at the AFFTC with little apparent return. The total Drop Model System, as ultimately developed, modified, and flown by the AFFTC test team was only reliable enough to permit accomplishment of the limited AFFTC objectives. The continuation of test operations without a major expenditure of resources to improve reliability was judged to be impractical.

THE GROUND CONTROL STATION

Because the project was so far behind schedule, the AFFDL requested that the contractor deliver the ground control station to Edwards AFB before he had completed development work on it; however, neither the AFFDL project personnel nor the AFFTC test team were aware of the quantity and the scope of the work yet remaining. Development of the interface system was not completed and the computer program had not been debugged or loaded into the computer memory. Other functions of the ground control station had not been demonstrated. Contractor personnel

were unable to determine whether specific problems were caused by programming errors because the personnel were without the test equipment and computer facilities required for the efficient completion of their development efforts. The contractor was released from all contract obligations when it became apparent that no progress was being made.

(CRITICAL) The reliability of the ground control station interface unit was a major source of delays in the program. Inadequate documentation and troubleshooting procedures continually hampered efforts to find the source of the frequent system failures.

1. A complete circuit analysis and redesign of the ground control station interface unit should be conducted with special emphasis on the system interrupt circuits between the minicomputer, telemetry system, digital-to-analogue converters, and test engineer's panel. Complete documentation and maintenance procedures must be produced (page 30).

(CRITICAL) The computer program originally written for the ground control station was repeatedly and extensively modified to produce a usable flight control system, and portions of the program which were not being used were never properly debugged. These modifications were difficult to understand and work with, slowed down computer operations, and may have been responsible for the spurious control surface commands and the noisy cockpit instruments observed during the program.

2. A new program should be written for the minicomputer to process the data from the telemetry downlink, drive the indicators in the cockpit, calculate the feedback inputs, and sum them with the pilot's control inputs to produce the commands to be issued on the telemetry uplink. The program should be modularized to provide a growth potential and facilitate future modifications to the flight control system (page 31).

(CRITICAL) No capability existed for recording the uplink telemetry signals, the pilot control inputs, the angle of attack and rate feedback inputs generated by the minicomputer, the cockpit instrument signals, or the general operation of the minicomputer and the interface unit. Checkout of the telemetry system and the ground control station (particularly the proper computation and transmission of the control surface commands) was difficult because no recording of these functions was possible. Detailed reconstruction of flight events depended upon individual memories and playback of the downlink telemetry recording made at the data acquisition facility.[29]

[29] The quality of the downlink telemetry signal received at the data acquisition facility may have differed from that received at the ground control station. Any degradation at the ground station could result in generation of improper control surface commands (i.e., the spurious commands noted above).

3. A 14 track tape recorder should be installed in the ground control station. The pilot's stick and rudder inputs and the analogue cockpit instrument signals should be digitized and multiplexed with the results of selected computer computations (the feedback inputs and the control surface commands) into a PCM data stream similar to the downlink data stream. This data stream, the uplink and downlink telemetry signals, the UHF radio communications, the interphone communications, and an Inter-Range Instrumentation Group (IRIG) master time code should be recorded for post-flight analysis and system troubleshooting (page 30).

(CRITICAL) The altimeter originally provided for the cockpit in the ground control station was unable to respond to the high descent rates encountered by the model shortly after launch. It also had the tendency to display a 1000-foot error. These deficiencies were remedied when a dc servomotor altimeter was temporarily installed in the cockpit for flight 3-D-3.

4. A dc servomotor altimeter should be permanently installed in the ground control station (page 32).

(CRITICAL) Intermittent interruption of the uplink command telemetry signal caused rapid control surface excursions and violent model gyrations on flights 3-D-2 and 3-D-3. Any misalignment of the tracking antenna on the ground control station could direct the command telemetry signal away from the model and cause the loss of uplink reception at the model.

5. The automatic tracking antenna system at the ground control station should be checked for proper operation and alignment (pages 58, 61).

(NONCRITICAL) No backup attitude sensor was installed in the Drop Model and, hence, real-time assessment of the validity or accuracy of the attitude information presented to the pilot was extremely difficult. Any attitude gyro which would be installed in the model as a backup would be subject to the same drift and tumbling problems encountered by the primary system.

6. A television camera and transmitter should be installed in the model and a receiver, recorder, and 17-inch monitor should be installed in the ground control station to enable the pilot and the test engineer to make real-time assessments of the model attitude. The television picture would also be extremely valuable to the pilot if he was forced to land the model on the dry lakebed if the parachute recovery system failed[30] (pages 52, 57, 58, 61).

[30]This recommendation is identical to recommendation No. 17. It was included under both THE GROUND CONTROL STATION and THE MODEL because it pertains to both systems and might be overlooked as a ground control station recommendation if it were presented only under THE MODEL and vice-versa.

(NONCRITICAL) The center control stick and the rudder pedals in the ground control station cockpit exhibited large deadbands about the center positions in all axes. The return springs were very difficult to adjust and did not provide force gradients which were confortable to the pilots.

7. The present control stick and rudder pedals in the ground control station should be replaced with a hydraulic force-feel system of the type presently used in ground based simulators (page 32).

(NONCRITICAL) All programming and entry of model sensor calibrations in the ground control station minicomputer was manually accomplished in machine language through the direct memory access console (DMAC). This was an extremely tedious process which increased the probability of error and the difficulty of locating or recognizing the error.

8. A card reader and FORTRAN compiler should be installed in the ground control station to facilitate programming of the computer (page 31).

THE MODEL

Because the contractor did not sufficiently consider the accuracy, stability, and reliability of the data required to accomplish the AFFDL program objectives, some of the dynamic instrumentation data sensors in the models (the air data sensors and the attitude gyro) were inadequate in those respects. The stability and reliability were definitely unacceptable for use in the Drop Model operational environment. The scaling of the longitudinal accelerometer exemplified the contractor's lack of appreciation for the flight test data requirements. Inadequate consideration was given to the reliability and continuity requirements for both the uplink and downlink telemetry signals. The telemetry antenna patterns and the telemetry signals were apparently blocked at certain model attitudes. The model impact attenuation features were inadequate and the drogue parachute originally provided was not acceptable; these facts exemplified the inadequacy of the contractor's design in those areas.

(CRITICAL) The attitude reference system in the model was not acceptable for the drop model mission. Even the small drift rate specified for the unit produced unacceptable biases in all three axes at launch. Uncaging the gyro with the model under tow also introduced an unknown bias which significantly diminished the precision with which the pilot was able to control the model and perform the desired data maneuvers. The unknown biases also prevented calculation of the flight-path angle and the upwash correction for the angle of attack. Numerous internal mechanical failures occurred in the gyro units which delayed both development efforts and model flights.

9. The attitude reference gyro should be replaced with a more reliable unit. The replacement unit should retain the 360-degree range and tumble-free operation in all three axes originally specified, and, if possible, it should include a self-erecting mechanism which can be locked out shortly before launch (pages 22, 57, 58, 61).

10. If a replacement with a suitable self-erecting mechanism cannot be obtained, a second, two-axis, self-erecting gyro should be installed in the model to provide a bias correction at launch. The ground control station minicomputer should then be programmed to use that bias to provide corrected pitch and roll attitude information to the model pilot in real time. Corrected attitude information should be used in postflight data analysis to calculate flightpath angle, upwash corrections, and other flight parameters (pages 22, 57, 58, 61).

(CRITICAL) The air data system installed in the model by the contractor did not provide altitude, airspeed, angle of attack, and angle of sideslip data with sufficient accuracy or reliability. An extended warmup period was required prior to calibration of the static and differential pressure transducers, and repeatability of the output was unacceptable. Two static pressure transducers operated over different ranges to increase accuracy, but they yielded conflicting results where their ranges overlapped because the output of one or both had drifted due to temperature effects. The Datametrics differential pressure transducer which was temporarily installed for flight 3-D-3 provided excellent data. The value of using a second pitot tube more closely aligned with the relative wind for high angle of attack flight was not determined.

11. Pressure transducers exhibiting accuracy, resolution, and temperature stability at least as good as the Datametrics unit should be installed throughout the air data system. A single transducer should be used to acquire static pressure data throughout the model's altitude range. If necessary, two telemetry data words should be used to provide the required accuracy and resolution (pages 20, 21, 22, 58).

(CRITICAL) The operating range of the longitudinal accelerometers did not permit direct calculation of the model chord force coefficient. This necessitated the use of an iterative process to calculate lift and drag coefficients for comparison with full-scale YF-16 lift and drag data.

12. The range of the longitudinal accelerometer should be modified to ± 0.5 g's to permit direct and accurate computation of model performance parameters (pages 23, 84).

(CRITICAL) Intermittent interruption of the uplink command telemetry signal caused rapid control surface excursions and violent model gyrations on flights 3-D-2 and 3-D-3. A nonspherical receiver antenna pattern was postulated to have caused the loss of signal at certain model attitude.

13. Both the uplink and downlink antenna systems should be redesigned to provide optimum telemetry communications at any model attitude. The antenna should be flush mounted or internally mounted to maintain precise similarity between the model and the full-scale YF-16 aircraft (pages 58, 61).

(CRITICAL) The landing shock attenuation system (the foam-filled underbelly of the model) was only marginally effective. Landing forces were transmitted, by the fiberglass skin which covers the foam, to the main fiberglass sections which comprise the model fuselage. Only minor cracks appeared around the joints between the underbelly fiberglass and the fuselage components; the underbelly fiberglass did not crack and the foam showed no evidence of compression. Cracks appeared in the strakes forward of the wings roots, and the simulated AIM-9 missiles and launch rails were torn from the wingtips by the "g" forces. Landings in other than a level attitude (in both pitch and roll) on other than level terrain resulted in moderate but repairable damage in the areas of contact.

14. The foam underbelly of the model should be replaced with a deployable air filled bag or by a deployable foam-in-place system similar to the one being tested by Mehaffie[31] for the AQM-34V and BGM-34C remotely piloted vehicles. The new system should be designed to provide impact load attentuation sufficient to reduce landing forces to 8 g's or less, to permit landings at attitudes up to 30 degrees in pitch and roll with no increase in expected damage, and to provide support for the wings and missiles at landing (page 58).

15. If an air bag or foam-filled bag system cannot be installed in the Drop Model, the rigid foam in the belly should be replaced with less dense, more crushable foam which would transmit less impact energy to the model structure. The fiberglass skin should be made considerably more frangible, either by purposely scoring the inside of the present skin to weaken it or by replacing it with a thinner skin (page 58).

(NONCRITICAL) The model performance was inferior to that of the full-scale YF-16; the model lift and normal force coefficients showed significant reductions and the drag coeeficient showed an increase over those of the full-scale aircraft.

16. The model should be examined in detail to determine whether it conforms exactly to the exterior shape of the full-scale YF-16 aircraft, and differences should be corrected where possible. Consideration should be given to reducing the aerodynamic interference caused by the blocked air intake by removing some of the foam and exhausting the air around the outside of the parachute cannister in the "engine bay". Reduction of the parasite drag caused by surface irregularities at the control surface hinge lines, around the access panels

[31] Reference 5: Mahaffie, Stephen R., Investigation of a Deployable Foam Ground Impact Attentuation System for Aerospace Subsystems, AFFDL-TR-(TR number not assigned), Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, to be published. A foam-in-place system uses two chemicals which react to forma polyurethane foam to provide the impact attentuation. The foam would be mixed and sprayed into a shaped, deployable bag beneath the model fuselage immediately after the model repositioned to the horizontal attitude. The density of the foam and the shape of the bag would be tailored to provide the attentuation characteristics desired.

and fasteners, at the leading edge flap mounts, and at the parachute riser channels and mounts should also be considered (pages 68, 85).

(NONCRITICAL) No backup attitude sensor was installed in the Drop Model and, hence, real-time assessment of the validity or accuracy of the attitude information presented to the pilot was extremely difficult. Any attitude gyro which would be installed in the model as a backup would be subject to the same drift and tumbling problems encountered by the primary system.

17. A television camera and transmitter should be installed in the model and a receiver, recorder, and a 17-inch monitor should be installed in the ground control station to enable the pilot and the test engineer to make real-time assessments of the model attitude. The television picture would also be extremely valuable to the pilot if he was forced to land the model on the dry lakebed if the parachute recovery system failed[32] (pages 52, 57, 58, 61).

(NONCRITICAL) No capability existed for releasing the drogue and main parachutes from the model in flight if the parachutes were damaged or partically deployed.

18. The parachute system should be modified to permit release of the drogue and main parachutes on command from the ground control station.

(NONCRITICAL) Chase pilots and photographers repeatedly commented on the difficulty of maintaining visual contact with the model because of its small size.

19. The model paint scheme should be revised to improve visibility and still retain the capability to instantly determine the model attitude and direction of flight. This would also facilitate postflight analysis of optical tracking film (pages 20, 52).

HELICOPTER SYSTEMS

(NONCRITICAL) The flight time available on each Drop Model was marginally acceptable due to the reduced performance of the model and the inability of the launch helicopter to climb above 16,500 feet with the model in tow. A 4,500-foot increase in launch altitude would produce a 40-percent increase in available flight time, and a 25,000-foot launch altitude would yield 6 minutes of test time per flight.

20. If possible, a different launch helicopter should be selected which will be capable of safely achieving a 25,000-foot launch altitude with a 1,000-pound payload and four crewmembers (page 34).

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[32] This recommendation is identical to recommendation No. 6. It was included under both THE GROUND CONTROL STATION and THE MODEL because it pertains to both systems and might be overlooked as a model recommendation if it were presented only under THE GROUND CONTROL STATION and vice-versa.

REFERENCES

1. Woodcock, Robert J., Some Notes on Free Flight Model Scaling, AFFDL-TM-73-123-FGC, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, August 1973.

2. Retelle, John P. Jr., Meausred Weight, Balance, and Moment of Inertia of the X-24A Lifting Body, FTC-TD-71-6, Air Force Flight Test Center, Edwards AFB, California, November 1971.

3. Nagy, Christopher J., A New Method for Test and Analysis of Dynamic Stability and Control, AFFTC-TD-75-4, Air Force Flight Test Center, Edwards AFB, California, May 1976.

4. Layton, Garrison P., "A New Experimental Flight Research Technique: The Remotely Piloted Airplane", Agard Conference Proceedings No. 187, April 1976, Hartford House, London, UK.

5. Mahaffie, Stephen R., Investigation of a Deployable Foam Ground Impact Attenuation System for Aerospace Subsystems, AFFDL-TR-(Number Not Assigned), Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, to be published.

APPENDIX A

CHECKLISTS

Stall/Spin Drop Model Program JON 1917B0

MASTER CHECKLIST FILE

Checklist	Distribution*
1. YF-16 Remotely Piloted Research Vehicle Intermediate Preflight checklist, Phase 1 (Model Preparation)	5 copies TD, IE
2. Control Van Preflight checklist	10 copies TD, MP, TE, SM, ST
3. Control Van Preflight Cockpit checklist	10 copies TD, MP, TE, SM, ST
4. YF-16 Remotely Piloted Research Vehicle Intermediate Preflight checklist, Phase 2 (Control Van/Model Interface)	5 copies TD, IE, SM, ST
5. YF-16 Remotely Piloted Research Vehicle Pyrotechnic Device Installation checklist	5 copies TD, CC, ACC **
6. YF-16 Remotely Piloted Research Vehicle Parachute Installation checklist	5 copies TD, CC, ACC **
7. YF-16 Remotely Piloted Research Vehicle/ Control Van Final Preflight checklist (Morning of flight)	10 copies TD, IE, MP, TE, SM, ST, DM's
8. UH-IN Helicopter Class II Modification Equipment Installation checklist	5 copies TD, LBO, HM, HCC's
9. YF-16 Remotely Piloted Research Vehicle/ UH-IN Helicopter Mating checklist	10 copies TD, IE, CC, ACC, LBO, HM HCC's
10. UH-IN Helicopter/YF-16 RPRV In-Flight Tow Procedures checklist and Emergency Procedures (Flight Cards)	25 copies TD, MP, TE, SM, ST, HP, HCP, LBO, HM, SC, PH, DM's TO, RC's, OB's

MASTER CHECKLIST FILE (concluded)

Checklist	Distribution*
11. YF-16 Remotely Piloted Research Vehicle Test Procedures checklist and Emergency Procedures (Flight cards)	25 copies TD, MP, TE, SM, ST, SC, PH, DM's, TO, RC's OB's
12. YF-16 Remotely Piloted Research Vehicle Recovery Team checklist	10 copies TD, DF's, RT's

*Distribution Abbreviations

ACC	Model Assistant Crew Chief
AIE	Assistant Instrumentation Engineers
CC	Model Crew Chief
DF	Downfall Range Personnel
DM	Data Monitors
HCC	Helicopter Crew Chief
HCP	Helicopter Copilot
HM	Helicopter Mechanic
HP	Helicopter Pilot
IE	Instrumentation Engineer
LBO	Launch Box Operator
MP	Model Pilot
OB	Observers
PH	Photographer
RC	Radar Controller
RT	Recovery Team Members
SC	Safety Chase Pilot
SM	Systems Monitor
ST	Systems Technician
TD	Test Director
TE	Test Engineer
TO	Test Operations (6512th Test Squadron)

** Munitions Maintenance and Parachute personnel will provide adequate numbers of their checklists for their own use.

STALL/SPIN DROP MODEL PROGRAM

JON 1917B0

YF-16 REMOTELY PILOTED RESEARCH VEHICLE

FUNCTIONAL CHECKLIST

PHASE 1 (Model Preparation)

Flight Number____________ Tail Number_________________

Completed by _______________________ __________
Instr Technician (LG) Date

Approved By_________________________ __________
Instr Engineer (DOESI) Date

COMMENTS:

YF-16 REMOTELY PILOTED RESEARCH VEHICLE FUNCTIONAL CHECKLIST

PHASE 1 (Model Preparation)

_____ 1. Connect Power (+15 vdc, -15vdc and 28 vdc) to the Air Data Sensor (ADS) using the warmup power cable and the necessary power supplies.

_____ 2. Charge the Main and Aux batteries to be used onboard the model per charging instructions for partially discharged batteries.

_____ 3. Install the Pyro Test Box and connecting harness to the pyro connectors.

_____ 4. Install the surface protractors on the model.

_____ 5. Internal hydraulics connected and serviced.

_____ 6. Disconnect the J2 plug from the AIU and using the mating cable, connect the J2 outputs on the AIU Test Set to the J2 connector on the AIU.

_____ 7. Using the shorting lead, connect "Uplink Loss" jack on top of AIU test set to pin H (hotel) of the multipin female connector on the receiver. This will bypass the "loss of uplink" input to the AIU.

_____ 8. Connect the power harness to the top of the AIU test set (banana jacks) and to the power source plug in the model.

_____ 9. Check that all the switches are in the down position except the "Emer Con" switch (up position) on the AIU test set. Set all pots clockwise.

_____ 10. Power up the Instrumentation Ground Test Cart and turn on the bit synchronizer and decommutator modules.

_____ 11. Connect a coax cable between the "data" source on the AIU of the model to the PCM Source 2 input on the test cart.

_____ 12. Check that the PCM source and code (BIØ-S) are correct on the synchronizer and that the proper patching is installed on the decom module.

_____ 13. Connect the umbilical cable between the model (orange band will show on model connector when it's completely installed) and the side of the Helicopter Monitor System (HMS).

_____ 14. Check that the Master Power Switch in the model is in the "off" position.

_____ 15. Connect the power source leads to the side of the HMS and to a suitable 28-vdc source. Circuit Breaker on HMS should be "out", power switch position to "model power", and "ARM TEST" switch up.

_____ 16. Connect the ground support power cable to the MAIN and AUX battery connectors on the model and a 28-vdc source (can be the same source as used in step 14).

_____ 17. Recheck that the models "Master Power Switch" is "off", the breaker on the HMS is "out" and the switch on the HMS is in "model power". Set the following circuit breakers on the Power Distribution Panel in the model to the "in" position - ±15/+14, Encoder, ±5, X-Ducer, Four (4) CHUTE DEPLOY breakers (2 main and 2 aux), ADS, and accelerometer.

_____ 18. Check that the Baro Switches (2) are disconnected.

_____ 19. Check that the cage override switch on the attitude Gyro monitor box (GMB) is in the "MAN CAGE" position.

_____ 20. Verify that the dummy lanyard pins are installed.

_____ 21. Turn "on" and adjust the external power supply connected in Step 15 and 16.

_____ 22. Switch the Master Power Switch in the model to the "ON" position. Note the hum (3KHZ) from the Servocontroller Box.

_____ 23. Verify lock on the decommutator (ground cart) and select word #1 on the "binary display" selection switch. All ten lights should be "on" (lit).

_____ 24. Test each "Flight Control Mode" switch on the AIU Test Set by throwing the switch in the "up" position. One light on the decom display should go off (starting with the LSB) with each Flight Control Mode switch on the decom display.

_____ 25. Throw the "Spin Recovery" switch to the up position on the AIU Test Set and note the sixth (LSB=First) light go out on the decom display.

_____ 26. Reset the five "Flight Control Mode" switches and the "Spin Recovery" switch to the down position. The six corresponding lights should come back on.

_____ 27. Disconnect the Q switch in the forward section of the model while noting the 7th light. The light should go out as the switch is disconnected.

_____ 28. Reconnect the Q switch. The light should come on.

_____ 29. Check operation of Manual Nose Lift Switch on HMS.

_____ 30. Pull the dummy lanyard pins and set aside.

_____ 31. Disconnect the umbilical from the side of the HMS. Wait 15 seconds to allow onboard delays to expire and assure no unexpected chute deployment.

_____ 32. Throw both "ARM CMD Switches" up on the AIU Test Set. The ARM CMD light (#8) should go out after a short delay (less than 2 seconds). _____ sec.

_____ 33. Throw both "DROGUE CMD" switches up on the AIU Test Set. The DROGUE CMD light (#9) should go out and the Pyro Test Box should show the drogue gun would have fired (two green lights will come on). Wait 15 seconds to assure no further chute activity. _____ sec.

_____ 34. Throw both "MAIN CMD" switches up on the AIU Test Set. The MAIN CMD light (#10) should go out and the Pyro Test Box should show the drogue riser release in less than 2 seconds, with the intermediate riser release sequence 10 seconds later (eight more green lights should light up). Allow sufficient time for the sequence to occur (20 seconds maximum). _____ / _____ sec.

_____ 35. Reset the CMD switches (6) on the AIU Test Set to their down position; the CMD lights (3) on the decom should light again.

_____ 36. Install the dummy lanyard pins. All the lights on the Pyro Test Box should go out.

_____ 37. Select word #2 for the Binary Display on the decom module in the ground cart. Pull lanyard pins.

_____ 38. Using the "ARM", "DROGUE", and "MAIN" chute commands as done previously - activate chute deployment while monitoring the first seven lights of discrete word #2. The lights should correspond to pairs of lights on the pyro test box as follows:

- _____ 39. Drogue gun fired - (LSB) #1 light.
- _____ 40. Drogue Riser Release #1 - 2d light.
- _____ 41. Drogue Riser Release #2 - 3rd light.
- _____ 42. Intermediate Riser Release #1 - 4th light .
- _____ 43. Intermediate Riser Release #2 - 5th light .
- _____ 44. Connect both baro switches and the impact switch bypass plug.
- _____ 45. Main FWD Riser Release - 6th light .
- _____ 46. Main Aft Riser Release - 7th light .

_____ 47. Install lanyard pins to reset logic and lights .

_____ 48. Reset ARM, DROGUE, and MAIN CMD switches on AIUTS .

_____ 49. Disconnect both baro switches and the impact switch bypass plug.

_____ 50. Connect the umbilical to the connector on the side of the HMS.

_____ 51. Monitor the last three lights (#8, #9, #10) of discrete word 2 to see that they reflect the commutated code being generated onboard the model (two solid lights - one fluttering at approximately 20 Hz) and that the subcom sync is locked up.

_____ 52. Select word #3 for the Binary Display on the decom module in the ground cart.

_____ 53. Throw the "loss of Downlink" switch on the AIU Test Set up while noting the second light on discrete word #3. The light should go out with the switch up.

_____ 54. Reset the "Loss of Downlink" switch to the down position. The second light should light up.

_____ 55. Verify that all the switches on the AIU Test Set are down except for the "Emer Con" switch.

_____ 56. Push circuit breaker on HMS (Helicopter Monitor Box) in and confirm 28-32 volts on the voltmeter scale (designated "WELDER") in the face of the box.

_____ 57. Three green lights should be lit on the HMS at this time.

_____ 58. Switch the "ARM TEST" switch to test (down) and associated green light should go out and the associated amber light come on.

_____ 59. Switch the "ARM TEST" switch back to the up position. The amber light should go out and the green light come back on.

_____ 60. Cycle the "Umbilical Test" switch both up and down. In both the up and down positions the associated green light should go out and the associated amber light come on.

_____ 61. Pull one lanyard pin and check that the associated green light goes out and its amber light comes on. Reset the lanyard pin.

_____ 62. Repeat step 59 with the second lanyard pin.

_____ 63. Switch the power mode switch on the HMS to "helicopter power."

_____ 64. Verify that the control surfaces are cleared to allow full throw movement.

_____ 65. Turn on the "Hyd Man" switch on the Power Distribution Box and push both hydraulic circuit breakers in (external breaker and one on power distribution box). The hydraulic system should <u>not</u> come on.

_____ 66. Check fluid volume on the accumulator of the hydraulic pump - it should be 8cc or greater and should return to this level anytime the pump shuts off.

_____67. Cycle the "Cont Surf Test" switch on the HMS while noting that the system comes on and levels off at 1500 psi on the pressure gauge. Release the switch.

_____68. Activate the "Emer Con" switch (down) on AIU Test Set. Hydraulics should come on in 1 second and discrete light #3 on decom lights up. Allow the hydraulic system to operate while checking for unusual noises, leaks, etc. (about 30 seconds). Reset the "Emer Con" switch to turn hydraulics off.

_____69. Unplug ADS warnup cable and connect onboard plug.

_____70. Set the "Nose Lift" circuit breaker on the Power Distribution Box and lower the noise of the model; locking it in the flying position.

_____71. Switch power from "Hel" to "Model" power on HMS. The hydraulics should come on - pull the external hydraulic breaker to turn them off.

_____72. Pull the lanyard pins and umbilical plug. All the amber lights and the red light on the HMS should light.

_____73. Cycle "launch" switch on HMS, all the lights should go out.

_____ 74. After approximately 20 seconds connect the two baro switches and observe the "drogue gun" lights (2) on the pyro test box come on.

_____ 75. When Drogue Release lights light, push in external hydraulic breaker.

_____ 76. "Drogue Release" lights on pyro test box light in 10 seconds.

_____ 77. "Intermediate Release" lights on pyro test box light in an additional 10 seconds. The "nose lift" motor should start and the hydraulics turn off automatically.
_____ / _____ / _____ sec.

_____ 78. Cycle "Emer Con" switch on AIUTS down.
a. Nose lift motor should reverse and reset.
b. Hydraulic motor should restart.

_____ 79. Return "Emer Con" switch to original position (up).
a. Nose lift motor should start and nose should lift.
b. Hydraulic motor should shut down.

_____ 80. Insert test plug into "impact switch" bypass plug and note "Riser Release" lights come on on pyro test box. All lights should now be on.

_____ 81. Insert lanyard pins. The nose lift motor will start again until it resets itself. The hydraulic pump starts. The chute logic resets and the pyro test box lights go out. Turn off "Hyd Man" on power distribution box and pull the hydraulic circuit breaker (external) out to turn hyd off.

_____ 82. After the nose lift motor stops, pull the "nose lift" circuit breaker on the power distribution box.

_____ 83. Remove the impact switch test plug and disconnect the baro switches (2).

_____ 84. While noting the "model release" (#9) and "3 second delay"discrete lights, pull the lanyard pins. Both lights should light (3-second delay on latter). _____ sec.

_____ 85. Allow the model to "fly" for 30 seconds while watching the pyro test set - no lights should light.

_____ 86. While watching discrete light #4 on decom, switch the "loss of sync" switch on the AIU test set. The light should go out. The drogue lights on the pyro test set should come on in 10 seconds followed by the drogue release lights in 10 more seconds and finally the intermediate lights in 10 more seconds. _____ / _____ / _____ sec.

_____ 87. Plug in the impact switch test plug, nothing should happen (allow 30 seconds).

_____ 88. Unplug impact test plug and connect baro switches while noting discrete light #7 on the decom (should come on). No additional lights on pyro test box. _____ sec.

_____ 89. Plug in impact switch test plug and "main riser" release lights should light.

_____ 90. Insert dummy lanyard pins and chute logic should reset. Disconnect baro switches and remove the impact switch test plug.

_____ 91. Reset "Loss of Sync" switch on AIU test set while noting the decom light comes on.

_____ 92. Pull lanyard pins again and allow 30 seconds - nothing happen.

_____ 93. Cycle the "Loss of Uplink" switch on the AIU test set up. The 5th discrete light should go out and the drogue should fire in 10 seconds. _____ sec.

_____ 94. Replace lanyard pins. Logic should reset.

_____ 95. Reset the "Loss of Uplink" switch on the AIU test set and note the corresponding decom light comes on.

_____ 96. Pull lanyard pins and allow a 30-second "nothing should happen" period.

_____ 97. Remove connector from Q switch, drogue gun should fire immediately (allow 3-sec delay to expire).

_____ 98. Replace lanyard pins and Q switch connector. Chute logic should reset.

_____ 99. Remove lanyard pins and wait 30 seconds. Nothing should happen.

_____ 100. Slowly decrease the voltage on the "aux power supply" pot on AIUTS until the main drogue gun light lights. This should occur around 21 to 23 volts (use DVM to monitor pot output). _____VDC.

_____ 101. Reset the logic by inserting the lanyard pins.

_____ 102. Reset the aux power supply pot to 28 vdc (fully clockwise).

_____ 103. Remove the lanyard pins again and wait 30 seconds.

_____ 104. Slowly decrease the "Main power supply" pot on AIUTS until the aux drogue gun fires (21 to 23 volts). _____VDC.

_____ 105. Reset the logic with the lanyard pins.

_____ 106. Reset the "Main power supply" pot to 28 volts.

_____ 107. Activate the "attitude gyro" circuit breaker on the power distribution box and note the audible hum as the unit comes up.

_____ 108. Verify the pyro test box plug is in the forward chute riser release plug.

_____ 109. Switch the caging scheme to "auto cage" on the gyro control box.

_____ 110. Switch the "gyro cage" switch on the AIU test set up while listening for an audible "clunk" and noting the #1 discrete light goes out. The gyro is now uncaged.

_____ 111. Remove pyro test box plug from Main Fwd riser connector - the gyro should begin to cage in 3 seconds. _____ sec.

_____ 112. Replace pyro test plug - the gyro should uncage.

_____ 113. Cage the attitude gyro by resetting the "cage" switch on the AIU Test Set down. Caging will occur in 3 seconds and the discrete light will come on.

_____ 114. Switch gyro control switch to "Man Cage" and then shut down the attitude gyro by pulling the respective circuit breaker on the power distribution box.

_____ 115. Connect the hydraulic mule to the model and the water cooling lines to the mule.

_____ 116. Set the "surface position CMD" thumb wheel switch on the AIU Test Set to #1. Monitor the rudder data channels while exercising the remote command pot and the mule on and adjusted to 600 psi. Record the three parameters for each setting at zero and full throw surface positions. Fill in Table 1.

THUMBWHEEL SETTING	SURFACE	CMD CHANNEL			POT CHANNEL			LVDT CHANNEL		
1	Rudder*	11			16			6		
2	Right Flaperon*	12			17			7		
3	Left Flaperon*	13			18			8		
4	Right Stabilator*	14			19			9		
5	Left Stabilator*	15			20			10		

*Go-No-Go Item

TABLE 1

_____ 117. Repeat step 113 for the other surfaces listed in Table 1.

_____ 118. Turn off mule.

_____ 119. Angle of attack (α) and angle of sideslip (β) will be checked by manually moving the vanes and monitoring parameters #38 and #32, respectively. Before completing Table 2, assure that the onboard power plug for the ADS is connected.

PARAMETER	DEGREES	COUNTS
#38*	-10 (TED)	
	0	
	+70	
#32*	-20 (TER)	
	0	
	+20	

*GO-NO-GO Item

TABLE 2

_____ 120. Power up the accelerometers and attitude gyro from power distribution box. Both gyro packages should have audible hum.

_____ 121. Uncage the attitude gyro.

_____ 122. Record the static parameter values in column 3 of Table 3 after a short warmup period.

PARAMETER	PARAMETER #	STATIC VALUE	FUNCTIONAL CHECK
Yaw Accel	25		
Pitch Accel	26		
Roll Accel	27		
Long Accel	28		
Yaw Ang*	29		
Pitch Ang*	30		
Roll Ang*	31		
Lat Accel	33		
Yaw Rate*	34		
Pitch Rate*	35		
Roll Rate*	36		
Norm Accel	37		

*Go-No-Go Item

TABLE 3

_____ 123. Suspend the model, using the launch rack and ceiling hook enough to physically excite and monitor the operation of the parameters listed in Table 3. Check off the parameter in column 4 of Table 3, after visual confirmation that the parameter is changing on the decom.

_____ 124. Replace the model in the dolly, but retain hook linkage for control van tests in Phase Two. Recage the gyro. Pull the breakers for the accelerometers and the attitude gyro.

_____ 125. Connect the pitot-static tester to the nose boom and complete Table 4. Under no circumstances should the ADS limits of 20,000 feet altitude (MSL) or 300 knots airspeed be exceeded.

PARAMETER	PARAMETER #	3,000 Ft	8,000 Ft	12,000 Ft
Lo Ang Static (Zero Airspeed)*	24			
		75 Knots	125 Knots	175 Knots
Hi Ang Dyn (Field Altitude)*	21			
			ADS on time →	
PARAMETER	PARAMETER #	12,000 Ft	15,000 Ft	19,000 Ft
Hi Ang Stat (Zero Airspeed)*	23			
		100 Knots	150 Knots	200 Knots
Lo Ang Dyn (Field Altitude)*	22			
Q switch check at field altitude - enter airspeed →				

*Go-No-Go Item

TABLE 4

_____ 126. Vent pitot-static tester to ambient, but leave unit connected to boom for control van tests in Phase 2.

_____ 127. Complete Table 5 for fixed voltage measurements. The AIU cover will have to be removed to get to the test points in column 3, the J2 connector reconnected to the AIU (shut down model momentarily), the main and aux power supplies variable, and the overheat (decade) box installed.

PARAMETER	PARA #	CARD/TP	READINGS	
			VOLTS	COUNTS
Spare (Grnd)	4-1	XJ12/1		
+15 VDC	4-2	XJ12/2		
-15 VDC	4-3	XJ12/3		
+5 VDC	4-4	XJ12/4		
OVDC CAL	5-1	XJ13/1		
2.5 VDC CAL	5-2	XJ13/2		
5 VDC CAL	5-3	XJ13/3		
0 VDC CAL	5-4	XJ13/4		
5 VDC CAL	5-5	XJ13/5		
Spare (Grnd)	5-7	XJ13/7		
Spare	5-8	XJ13/8		

TABLE 5

_____ 128. Complete Table 6 for variable voltage measurements and hydraulic parameters. Hydraulic pressure is sampled at zero pressure and full pressure. Hydraulic temp is an on/off function and is sampled at "on" level and at "off" level.

PARAMETER	PARA #	CARD/TP	VOLTS	COUNTS	VOLTS	COUNTS
			31 VDC		27 VDC	
28 VDC Main	4-5	XJ12/5				
28 VDC Aux	4-6	XJ12/6				
28 VDC Hyd	4-7	XJ12/7				
			Counts at Zero Press		Counts at Full Press	
Hyd Press.	4-8	XJ12/8				
			Counts at Cold Temp		Counts at Over Heat	
Hyd Temp	5-6	XJ13/6				

TABLE 6

_____ 129. Replace cover on AIU and secure AIU with straps.

_____ 130. Power model down.

_____ 131. Prepare for Phase Two Checklist (CL-4).

CONTROL VAN PREFLIGHT CHECKLIST

Control Van Start Up

1. Power up van

2. Insure that all power supplies are indicating proper voltage and current. They should read:

Master	15 volts	~	1.5A
Slave	15 volts	~	1.0A
	28 volts	~	2.0A
	5 volts	~	32.0A
	400 Hz	~	0.5A

3. Check 10-volt power supplies at Buss Bars in back of center rack. Check with voltmeter.

Buss Bar #2	~ +9.00	±.05 volts
Buss Bar #3	~ -9.00	±.05 volts

4. Slew antenna to approx 100°

5. Call Command Post Current Operations to obtain clearance to transmit on desired VHF and TM frequencies if not on printed sched.

6. Call Central Radio for UHF patch to transmit and receive on desired UHF frequency from the Control Van

7. Power up UHF and HAVE LAKE comm. boxes. If available, call Data Room and SPORT Radar for radio check on both links.

8. Check 16mm movie camera loaded and ready to use.

9. Check cassette tape recorder in place and ready to use.

Software Start Up

10. Reload computer if desired. Load preflight patch tape.

11. Start computer.

12. Cycle Autopilot Engage function at least once. THE A/P ENGAGE LIGHT IS NOT A DEPENDABLE INDICATOR UNTIL IT HAS BEEN CYCLED.

13. Input zero pitch rate and angle of attack.

14. Go to Min SAS mode and trim surfaces to zero.

15. Input $\alpha=10^{\circ}$, $P=20^{\circ}/s$, $Q=10^{\circ}/s$, and $R=100^{\circ}/s$.

16. Check surfaces in all FD Panel modes.

17. Confirm Angle of Attack and Yaw Rate meters read correctly.

CONTROL VAN COCKPIT SETUP CHECKLIST

1. Pilot's station switches - Set

   a. Emergency Parachute Deployment Switch - Cover down and safety wire fastened.

   b. Pyro Arm Button - Out (No red showing)

   c. Drogue Deploy Button - Out (No red showing)

   d. Main Deploy Button - Out (No red showing)

   e. Plastic cover for Manual Deployment Buttons - Down and Fastened

   f. Control Stick Select Switch - As desired

   g. Attitude Director Indicator Trim Knob - Set

   h. Headset - Plugged in

   i. UHF Radio and Intercom Volume Knobs - As desired

2. Test Engineer's Panel - Set

   a. All Flight Control Mode Select Buttons - Out (No red showing)

   b. Automatic Spin Recovery Button - Out

   c. Autopilot Disengage Button - Out

   d. Azimuth Slave Button - Out

   e. Flight/Simulate Mode Switch - Flight

   f. Gyro Switch - Cage

   g. Emergency Control Switch - Cover Down and Safety Wire Fastened

   h. RD-3 Variable Feedback Gain Potentiometers (3) - As desired

   i. UHF Radio and Intercom Volume Knobs - As desired

YF-16 REMOTELY PILOTED RESEARCH VEHICLE
FUNCTIONAL CHECKLIST, PHASE 2
(Control Van/Model Interface)

_____ 1. Obtain clearance to broadcast on 1511.5 MHz and 1712.0 MHz from Command Post at 73940.

_____ 2. Check that the external power supply used in phase one is connected to both the model main and aux inputs and the HMS power input.

_____ 3. Check that the HMS is connected to the model, it's circuit breaker is out, and the power select in "model" power.

_____ 4. Check that the "master" switch and "Hyd Man" switches in the model are "off".

_____ 5. Check that all the circuit breakers on the model except the following are in -

(a) external hydraulic breaker
(b) C - Band TX
(c) L - Band TX

_____ 6. Connect the model to the hydraulic mule per connection procedure.

_____ 7. When the control van is ready, assure the external power supply is up; then switch the master power switch to "on" and the circuit breaker on the HMS in.

_____ 8. Check the PLB status with the monitor procedures using the HMS lights and switches.

_____ 9. Check operation of nose lift switch on HMS.

_____ 10. Power up the L-Band TX and establish the TM link with the control van. Note the signal strength of the downlink in the van-_____dB.

_____ 11. Power up ground test cart.

_____ 12. Check the downlink discretes to assure that the link is complete.

- _____ (a) Uplink Sync
- _____ (b) Uplink RF
- _____ (c) Downlink RF

_____ 13. Switch Gyro Monitor Box (GMB) to "auto" cage and have the control van exercise the cage/uncage gyro command.

_____ 14. Recage the gyro and put the GMB into "Man" cage. The attitude gyro breaker can be pulled to decrease the noise if desired.

_____ 15. Disconnect the external power connection to the ADS and reconnect the onboard power plug <u>after</u> assuring the ADS breaker is in.

_____ 16. Complete tables #1 and #2 for the ADS parameters listed using methods from phase one to generate the inputs. (Steps 112 and 117).

	PARA #	12,000 ft	15,000 ft	19,000 ft
		Counts	Counts	Counts
HI ANG STATIC (Zero airspeed)	23			
	PARA #	100 knots	150 knots	200 knots
		Counts	Counts	Counts
LO ANG DYN (Field altitude)	22			

TABLE 1 (MODEL)

	PARA #	12,000 ft	15,000 ft	19,000 ft
		Cockpit	Cockpit	Cockpit
HI ANG STATIC (Zero airspeed)	23			
	PARA #	100 knots	150 knots	200 knots
		Cockpit	Cockpit	Cockpit
LO ANG DYN (Field altitude)	22			

TABLE 2 (JAN)

_____ 17. Reconnect Pitot-Static tester to the HI ANG DYN/LO ANG STAT-system and bring the airspeed to 100 knots on the tester. With the α protractor installed, slowly increase the angle of attack (TEU) until the cockpit display registers the HI ANG DYN airspeed value. Record the α value in table #3, add 5^{o} to AOA and then complete table #3 and #4.

ALPHA SWITCHOVER VALUE				
	PARA #	3,000 ft	8,000 ft	12,000 ft
		Counts	Counts	Counts
LO ANG STAT (Zero airspeed)	24			
	PARA #	75 knots	125 knots	175 knots
		Counts	Counts	Counts
HI ANG DYN (Field altitude)	21			

TABLE 3 (MODEL)

ALPHA SWITCHOVER VALUE				
	PARA #	3,000 ft	8,000 ft	12,000 ft
		Cockpit	Cockpit	Cockpit
LO ANG DYN (Zero airspeed)	24			
	PARA #	75 knots	125 knots	175 knots
		Cockpit	Cockpit	Cockpit
HI ANG DYN (Field altitudes)	21			

TABLE 4 (VAN)

_____ 18. Disconnect the pitot-static tester and stow until phase three.

_____ 19. Start the mule and adjust to approximately 1000 psi.

_____ 20. With the cockpit commanding an off-zero cmd (OZ), the HMS in "model pwr" and the model under tow (HMS installed), the surfaces should be at zero degrees.

_____ 21. Switch the HMS into "hel" pwr - the surfaces should remain at neutral even though the cockpit commands are OZ.

_____ 22. Cycle the "cont surf test" switch on the HMS down - the surfaces should respond to the "OZ" cmd.

_____ 23. Release the CST switch on the HMS, the surfaces should return to neutral.

_____ 24. Cycle the "Emer Control" switch in the cockpit. After a short delay (approx 1 to 2 sec), the surfaces should respond to the OZ cmds. Release the OZ command.

_____ 25. From the cockpit, trim all the surfaces to protractor zero while under "Emer Con". The α-vane must be set to waterline zero since it affects stabilator position.

_____ 26. Zero the cockpit position meters in the control van with model surfaces zeroed.

_____ 27. Inputing commands from the cockpit, complete the checks listed in tables #5 and #6. Enter both direction and position (degrees) for each event. Note that the α-vane is at waterline zero and the trim settings are set in Step 25.

	RUDDER		LEFT FLAP		LEFT STAB.		RT. STAB.		RT. FLAP	
EVENT	DEG	SENSE	DEG	SENSE	DEG	SENSE	DEG	SENSE	DEG	SENSE
Right Roll	0	N/A	20	TED	5	TED	5	TEU	20	TEU
Left Roll	0	N/A	20	TEU	5	TEU	5	TED	20	TED
Right Rudder	30	TER	0	N/A	0	N/A	0	N/A	0	N/A
Left Rudder	30	TEL	0	N/A	0	N/A	0	N/A	0	N/A
Pitchup	0	N/A	0	N/A	25	TEU	25	TEU	0	N/A
Pitch Down	0	N/A	0	N/A	25	TED	25	TED	0	N/A

TABLE 5 (MODEL)

EVENT	RUDDER		LEFT FLAP		LEFT STAB.		RT. STAB.		RT. FLAP	
	DEG	SENSE	DEG	SENSE	DEG	SENSE	DEG	SENSE	DEG	SENSE
Right Roll	0	N/A	20	TED	5	TED	5	TEU	20	TEU
Left Roll	0	N/A	20	TEU	5	TEU	5	TED	20	TED
Right Rudder	30	TER	0	N/A	0	N/A	0	N/A	0	N/A
Left Rudder	30	TEL	0	N/A	0	N/A	0	N/A	0	N/A
Pitchup	0	N/A	0	N/A	25	TEU	25	TEU	0	N/A
Pitch Down	0	N/A	0	N/A	25	TED	25	TED	0	N/A

TABLE 6 (VAN)

_____ 28. Cycle the trim on each surface stop to stop and record the surface deflections in table #7. Reset the trims to zero as in step #25 when completed and check model surfaces to verify they come to zero.

HORIZONTAL STAB. (PITCH)				
SURFACE	Full Up Trim		Full Down Trim	
	degrees	sense	degrees	sense
Left Stab.				
Right Stab.				

FLAPERONS (ROLL)				
SURFACE	Full Left		Full Right	
	degrees	sense	degrees	sense
Left Stab.				
Left Flap				
Right Stab.				
Right Flap				

RUDDER (YAW)			
Full Right		Full Left	
degrees	sense	degrees	sense

TABLE 7

_____ 29. Turn off mule.

_____ 30. Turn on the attitude gyro if it was turned off in step 12. Switch the GMB to "auto" cage and uncage the gyro from the control van. Record the three reference angle parameter count values and uncaging time in table #8.

UNCAGE TIME (STEP 30)				Angles Step 30	Angles Step 38
PITCH ANGLE	PARA #30	Counts up	Counts Dwn		
YAW ANGLE	PARA #29	Counts RT	Counts LT		
ROLL ANGLE	PARA #31	Counts RT	Counts LT		
CAGE TIME (STEP 38)					

TABLE 8 (MODEL)

_____ 31. Raise the model or the hook enough to allow oscillations while operating from the mule and HMS power.

_____ 32. Complete table #8 and #9 for the attitude gyro and ADI (eight ball) information.

UNCAGE TIME (STEP 30) →				Angles Step 30	Angles Step 38
PITCH ANGLE	PARA #30	DEG UP	DEG Dwn		
YAW ANGLE	PARA #29	DEG RT	DEG LT		
ROLL ANGLE	PARA #31	DEG RT	DEG LT		
CAGE TIME (STEP 38) →					

TABLE 9 (JAN)

_____ 33. Complete tables #10 and #11 for static values of the three rates, then oscillate the model to check operation and sensing.

PARAMETER	STATIC VALUE	DYNAMIC RESPONSE MOTION	DYNAMIC RESPONSE SENSING
#34 - Yaw Rate		Yaw Right	Increase
		Yaw Left	Decrease
#35 - Pitch Rate		Pitch-up	Decrease
		Pitch Down	Increase
#36 - Roll Rate		Roll Right	Increase
		Roll Left	Decrease

TABLE #10 (MODEL)

PARAMETER	STATIC VALUE	DYNAMIC RESPONSE	
		MOTION	SENSING
Yaw Rate Large Meter		Yaw Right	+
		Yaw Left	-
Yaw Rate Small Meter		Yaw Right	+
		Yaw Left	-

TABLE 11 (VAN)

_____ 34. Turn the hydraulic mule on and bring the pressure up to approximately 1,000 psi.

_____ 35. Check the rate feedback loops (roll, pitch and yaw) by rocking the model and noting the sense of surface travel. The surfaces should counteract the direction of oscillation.

_____ (a) Pitch feedback
_____ (b) Roll feedback
_____ (c) Yaw feedback

_____ 36. Turn the hydraulics off.

_____ 37. While monitoring parameter #37 and the cockpit display for acceleration, lower the model into the cradle with a slight impact and note the operation and direction of travel of this parameter - increasing/decreasing - counts/g's.

_____ 38. Record the three reference angle parameter count valves and caging time in table #8.

_____ 39. Cage the gyro from the control van, switch the GMB to "Man" cage, and pull the attitude gyro circuit breaker.

_____ 40. Using the beta protractor, complete table #12 for the beta values listed. For this test the α vane must be set to plus 60° (TEU) as indicated on the cockpit display.

ANGLE OF SIDESLIP, #32		
Degrees	Counts	Cockpit
-20 (TER)		
-10		
-5		
0		
+5		
+10		
+20 (TEL)		

NOTE: Alpha vane set at +60 degrees.

TABLE 12

_____ 41. Remove the beta protractor and install the alpha protractor.

_____ 42. Complete table #13 for the alpha values listed.

ANGLE OF ATTACK, #38		
Degrees	Counts	Cockpit
-10 (TED)		
-5		
0		
+5 (TEU)		
+10		
+20		
+30		
+40		
+50		
+60		
+68		

TABLE 13

_____ 43. Turn hydraulics on and bring the pressure up to 1,000 psi.

_____ 44. Complete table #14 for alpha feedback information to the stabilators.

ALPHA FEEDBACK					
VANE SETTING	COCKPIT	RIGHT STAB.		LEFT STAB.	
Degrees	AOA	Degrees	Sense	Degrees	Sense
-10 (TED)					
0					
+10					
+30					
+60 (TEU)					

TABLE 14

_____ 45. Turn off hydraulics (mule).

_____ 46. Cycle "Emer Con" in the cockpit to "off".

_____ 47. Disconnect the hydraulic battery connector.

_____ 48. Check that the HMS is in "hel" power and push the external hydraulic circuit breaker in. Hydraulics should not come on (hyd manual switch should be on).

_____ 49. Turn on the attitude gyro and flip the GMB to "auto" cage. Uncage the gyro from the control van.

_____ 50. Check that the baro switches and impact plug are not connected.

_____ 51. Lower the nose and idle mule at 300 psi.

_____ 52. With the model under a "tow" configuration now, hold an OZ command on the stick and complete the discrete and command control checks (steps 49 to 82). For each step there are certain functions and lights that signify correct operation. These reactions are listed and should be checked off by the appropriate personnel. NOTE: FDP=Flight Directors Panel, CD=Cockpit Display, DD=Discrete Display, M=Model, GTC=Ground Test Cart.

_____ 49. Switch HMS to "model power.

_____ DD/GTC - Hyd on
_____ M - Hyd on

_____ 54. Pull umbilical cable from model. No changes.

_____ 55. Pull the lanyard pins at model.

_____ CD - Release light on
_____ CD - Control light on
_____ DD/GTC - Model released
_____ DD/GTC - Cmd lockout (on=cmds)
_____ DD/GTC - Safety Delay (3 sec) over
_____ M - Surfaces to OZ Cmd.

_____ 56. Wait 20 seconds, then punch the "ARM" button in the cockpit.

_____ CD - Armed light on (1 sec)
_____ DD/GTC - ARM CMD received (1 sec)

_____ 57. Wait 20 seconds, then punch the "DROGUE" button in the cockpit.

_____ CD - DROG CMDED (1 sec)
_____ CD - DROGUE gun fired (2 sec)
_____ CD - Control light out (2 sec)
_____ CD - Recovery light on (2 sec)
_____ DD/GTC - DROGUE CMD received (1 sec)
_____ DD/GTC - DROGUE gun fired (2 sec)
_____ DD/GTC - REF Volt CMD on
_____ M - Control surfaces go to zero (cycle hyd to get pressure) under OZ cond.
_____ M - DROGUE gun fired on PTB.

_____ 58. Wait 20 seconds, then punch the "Main" command button in the cockpit.

_____ CD - Main CMDED (1 sec)
_____ CD - Prog risers released (1 sec)
_____ CD - Interm risers released (11 sec)
_____ DD/GTC - Main CMD received (1 sec)
_____ DD/GTC - DROG risers #1 and #2 released (1 sec)
_____ DD/GTC - Int.risers #1 and #2 released (11 sec)
_____ M - DROG risers #1 and #2 lit on PTB. (1 sec)
_____ M - Int.risers #1 and #2 lit on PTB. (11 sec)

_____ 59. Insert impact plug in model for 10 seconds and <u>remove</u>.

_____ No change

_____ 60. Connect the two baro switches at the model. (Impact plug <u>out</u>).

_____ DD/GTC - Altitude less than 5500 feet.
_____ DD/GTC - Hyd off (6 sec)
_____ M - Hyd off (6 sec)
_____ M - Nose lift motor starts (6 sec)

_____ 61. As soon as nose lift starts have the cockpit switch to "Emer Con".

_____ CD - Control light on (3 sec)
_____ DD/GTC - Hyd on (3 sec)
_____ DD/GTC - Ref volt cmd off (3 sec)
_____ M - Hyd on (3 sec)
_____ M - Nose lift reverses (3 sec)
_____ M - Surfaces move to 0Z cmds.

_____ 62. Allow ten seconds of "Emer Con", then switch back to normal operation in cockpit.

_____ CD - Control light off
_____ DD/GTC - Hyd off
_____ DD/GTC - Ref volt cmd on
_____ M - Hyd off
_____ M - Nose lift motor starts and lifts nose (15-sec run time)

_____ 63. Plug in impact plug momentarily (until risers release on PTB) at model.

_____ DD/GTC - FWD and AFT risers release
_____ DD/GTC - Gyro cages (up to 90 sec)
_____ M - FWD and AFT risers release
_____ M - Gyro caged (up to 90 sec)

_____ 64. Reset the lanyard pins at model and chute command buttons in cockpit.

_____ CD - Release, control and recovery lights off
_____ CD - Deployment lights out
_____ CD - Command return lights out
_____ DD/GTC - Hyd on
_____ DD/GTC - Gyro uncaged
_____ DD/GTC - Deployment lights "undeploy" (7 lights)
_____ DD/GTC - Model release and safety delay lights reset
_____ DD/GTC - Chute cmds reset
_____ M - Hyd on
_____ M - Nose lift motor resets
_____ M - Gyro uncages
_____ M - PTB resets (lights off)

_____ 65. Install nose lift motor simulator.

_____ 66. Disconnect the baro switches at model.

_____ DD/GTC - Altitude greater than 5500 feet.

_____ 67. Pull the lanyard pins at model. All indications go to after launch status as in step 51.

_____ 68. After 20 seconds, connect the baro switches at the model. Witness chute deployment as noted in earlier steps in following sequence:

- _____ (a) Altitude less than 5500 feet
- _____ (b) Drogue gun fired
- _____ (c) Controls locked (ref voit cmd)
- _____ (d) Drogue riser release (10 seconds)
- _____ (e) Int riser release (20 seconds)
- _____ (f) Nose lift motor starts.

_____ 69. Impact model momentarily at model to continue sequence.

- _____ (g) FWD and AFT riser release

- _____ (h) Gyro cages (up to 90 sec)

_____ 70. Reset lanyard pins at model, disconnect baro and impact switches. All indicators revert to undertow conditions. (steps 62, 63, and 64).

_____ 71. Pull lanyard pins at model. All indications go to after launch condition. (step 48).

_____ 72. After 20 seconds, cycle the "Emer Deploy" switch in the cockpit.

- _____ FDP - loss of uplink
- _____ CD - loss of link
- _____ CD - drogue gun fired (10 sec)
- _____ CD - control light out (10 sec)
- _____ CD - Recovery light on (10 sec)
- _____ DD/GTC - loss of uplink
- _____ DD/GTC - loss of sync
- _____ DD/GTC - drogue gun fired (10 sec)
- _____ DD/GTC - ref volt. comd on (10 sec)
- _____ M - Drogue gun fired (10 sec)
- _____ M - Surfaces go to zero at link failure while under OZ cmd

_____ 73. Reset the lanyard pins at model before the 10 seconds elapse from drogue fire. Drogue release lights occur in 10 seconds if lanyards aren't reset soon enough.

_____ 74. Reset "Emer Deploy" switch. Conditions go to undertow configuration.

_____ 75. Pull the lanyard pins at model. Conditions go to launch configuration.

_____ 76. After 20 seconds, break the PCM stream going to the uplink transmitter by disconnecting J13 in control van.

_____ FDP - loss of uplink
_____ CD - loss of link
_____ CD - Drogue gun fired (10 sec)
_____ CD - Control light out, recovery light on (10 sec)
_____ DD/GTC - loss of sync
_____ DD/GTC - Drogue gun fired (10 sec)
_____ DD/GTC - Ref volt. cmd on (10 sec)
_____ M - control surfaces go to zero at link failure under OZ command.

_____ 77. Reset the lanyard pins before drogue release occurs.

_____ 78. Reconnect PCM stream to uplink transmitter (J13). All indications should revert to undertow configuration.

_____ 79. Pull the lanyard pins at the model. Conditions should go to after launch status.

_____ 80. After 20 seconds, change two bit switches in decom sync pattern in control van.

_____ FDP - loss of dwn link
_____ CD - loss of link
_____ GTC - loss of down link
_____ GTC - ARM and DROGUE CMD received (10 sec)
_____ GTC - drogue gun fired (10 sec)
_____ GTC - Ref volt. cmd on (10 sec)
_____ GTC - Main CMD received (20 sec)
_____ GTC - Drog risers released (20 sec)
_____ GTC - Inter risers released (30 sec)
_____ M - surface go to zero at link failure while under OZ cmd.
_____ M - drogue gun fires (10 sec) _____ sec.
_____ M - drogue risers released (20 sec) _____ sec.
_____ M - Interm risers released (30 sec) _____ sec.

_____ 81. Impact model momentarily at model.

_____ No change.

_____ 82. Remove impact and connect the baro switches.

_____ GTC - Alt less than 5500 feet
_____ M - Nose lift motor starts (6 sec)

_____ 83. Impact model momentarily at model.

_____ GTC - FWD and AFT risers released
_____ GTC - Gyro caged (up to 90 sec)
_____ M - FWD and AFT risers released
_____ M - Gyro caged (up to 90 sec)

_____ 84. Reset the lanyard pins, disconnect the baro and impact. switches. Reset the two sync bits on decom, and cycle simulate switch. All conditions should revert to under-tow configuration.

_____ 85. After clearance from the control van that their tests are complete and the software is in a loop, switch the GMB to "Man" cage and pull the following breakers on the power distribution box:

_____ (a) Attitude Gyro
_____ (b) L - Band TX
_____ (c) L - Band RX
_____ (d) Accelerometers

_____ 86. Turn off the Master Power Switch.

_____ 87. Check the hydraulic bay for excessive leaks.

_____ 88. Remove HMS and umbilical cable.

_____ 89. Remove surface protractors.

_____ 90. Check charge on Main and Aux batteries. Top off batteries if necessary.

Aux battery _____ 38 volts and less than 0.1 amperes*
Main battery _____ 38 volts and less than 0.5 amperes*

*Discontinue charge if current bottoms out and starts to increase again or if battery temperature is greater than 15°F above ambient.

_____ 91. Check the whole model for loose connectors, screws, etc. Tape and secure any loose wires.

_____ 92. Check and put final charge on the hydraulic battery. Charge at 36.0 VDC until current is less than 1.0 ampere or until temperature increases to 15°F above ambient. Stow charge cable.

_____ 93. Return all test leads to their proper place and stow.

_____ 94. Notify Beacon Lab (72595) to schedule a beacon check to be accomplished morning of flight (1 hour prior to scheduled lift-off). Try to schedule with Center Scheduling (72166), if possible (Mr Powell).

_____ 95. Have the following items completed or available for pyro installion:

- _____ (a) Pyro test box installed
- _____ (b) Impact plug installed
- _____ (c) Drogue gun slug (machined) available
- _____ (d) Drogue gun, shear screws (3), and mounting screws available and out of model
- _____ (e) Riser plate and mounting bolts available
- _____ (f) Mounting bolts for double-release mechanisms and single-release mechanisms available.
- _____ (g) Ground wire attached to model
- _____ (h) Drogue gun cap available
- _____ (i) Tape available
- _____ (j) Flight plug installed

_____ 96. Allow pyro and parachute installation. Assist with power hookups to model and with test equipment.

_____ 97. While pyro's are being installed, check to see that the radio truck(s) will be available and are in working order - get a UHF patch from Central Radio and check extension mike, radio truck and control van system. Check with Test Director.

_____ 98. Inquire as to whether the UHF patch has been requested for the morning preflight.

_____ 99. Check on the availability of a backup radio set (UHF or FM) and either extra batteries or an ac line cond.

_____100. Stow Pyro Test Box when the pyro people are through with it.

_____101. Stow the external power supply leads and shut off supply.

_____102. When pyro installation is complete, block aft end of model (have cap installed) or back model up to a wall.

_____ 103. Install the grounding plug in J110, after pyros are completed.

_____ 104. Continue with phase three preflight 2½ to 3 hours before scheduled lift-off.

_____ 105. Set up ADS warmup box and time clock to ADS to allow necessary hours of ADS on time for CL-7.

EMERGENCY PROCEDURES

FOR FIRE:

1. Fight fire; remove munitions.

2. Call 117 and give location Bldg. 1830. room 6.

3. Evacuate nonessential personnel to 50 feet.

4. Record time flames enveloped munitions.

5. Withdraw to 50 feet within two minutes after fire envelops munitions, or after arrival of firefighters, whichever occurs first.

FOR DROP/COLLISION:

1. Call EOD.

MODEL PREPARATION

_____ 1. Model Connected to Ground.

_____ 2. Lanyard Pins in.

_____ 3. Hyd Pwr c/b out (right side).

_____ 4. Remove Panel #2 (1/8" Allen).

_____ 5. Master Switch off.

_____ 6. Barometric Line P. 49 & P. 46 Disconnect.

_____ 7. Remove Panels #3 & #6 (1/8" Allen).

_____ 8. Check hyd pressure for zero (Panel #3).

RISER RELEASE MECHANISM PREPARATION
(Single Release Only)

_____ 1. Parachute Riser Installed to Release Mechanism.

_____ 2. Riser Release Arm Secure.

_____ 3. Cotter Pin Installed.

_____ 4. Bushing Torqued 150 in.-lb (7/8" socket).

RISER RELEASE MECHANISM PREPARATION
(Dual Release Only)

_____ 5. Parachute Risers Installed.

_____ 6. Riser Release Pins - Secure.

_____ 7. Bushings Torqued to 150 in.-lb (3/4" socket).

IMMEDIATELY PRIOR TO LAUNCH

_____ 1. Model Preparation checklist complete.

_____ 2. Connect Pyro Test Box P37-J37, P38-J38, P39-J39, P40-J40, P41-J41, P42-J42, P58-J58.

_____ 3. Connect Barometric Switch Lines.

_____ 4. Power on Master Switch.

_____ 5. All Lights Off on Pyro Box.

_____ 6. Pull Lanyard Pin - Main.

_____ 7. Main Lights On.

_____ 8. Remove Aux Lanyard Pin.

_____ 9. Aux Lights On.

_____ 10. Reinstall Main Pin.

_____ 11. Main Lights Off.

_____ 12. Reinstall Aux Pin.

_____ 13. Aux Lights Off.

_____ 14. Power Off.

_____ 15. Remove Pyro Tester.

_____ 15A. Zero Meter.

_____ 16. Set up PSM-6 for Stray Voltage.

_____ 17. Insert PSM-6 into Holes 2 & 3 of P. 37 (less than ½ volt).

_____ 18. Insert PSM-6 into holes 5 & 6 of P. 37 (less than ½ volt).

_____ 19. Repeat steps 17 & 18 for remaining connectors P38, 39, 40, 41, 42, 58.

_____ 20. Lanyard Pins Installed and Taped Secure.

_____ 21. Power On.

_____ 22. Insert PSM-6 probes in hole 2 & 3 of P. 37 (Less than ½ volt).

_____ 23. Insert PSM-6 Probes in hole 5 & 6 of P. 37 (Less than ½ volt).

_____ 24. Repeat steps 22 & 23 for remaining connectors P38, 39, 40, 41, 42, 58.

_____ 25. Power Off.

_____ 26. Disconnect Barometer Switch.

INITIATOR LOADING (DUAL RELEASE)

_____ 27. Lubricate Initiators, install and torque 150 in.-lb (3/4" socket).

_____ 28. Connect Plugs - Orange Band 1/16".

_____ 29. Install Riser Release Mechanism (5/16" Allen).

INITIATOR LOADING (SINGLE RELEASE)

_____ 30. Lubricate Initiators, install and Torque 150 in.-lb (3/4").

_____ 31. Connect plugs - Orange Band 1/16".

_____ 32. Install Riser Release Mechanism (7/16" socket).

INITIATOR LOADING (DROGUE GUN)

_____ 33. Pilot Chute Riser - Attached.

_____ 34. Cotter Pin Installed.

_____ 35. Drogue gun shield - Installed.

_____ 36. Drogue gun initiators - Lubricated Installed & Torqued to 350 in-lbs (1 1/8" socket).

_____ 37. Drogue gun connector - Installed Orange Band 1/16".

_____ 38. Drogue gun mechanism - Installed (1/8" Allen).

WARNING Do not stand in front of Drogue gun after connector installed especially during installation.

_____ 39. Block off area 40 ft behind model.

_____ 40. Placard.

DELAYED FLIGHT & DEARMING
(More Than 1 Day)

_____ 1. Lanyard Pins Installed - 2

_____ 2. C/B Hyd Pwr - Out

_____ 3. Master Power Switch - Off (Panel #2)

_____ 4. Remove Panel #3 & #4

_____ 5. Hyd Pressure Zero

_____ 6. Remove Drogue Gun Assembly

_____ 7. Disconnect P38 (Drogue Gun)

_____ 8. Install Shorting Plug

_____ 9. Remove P. 41 (single release) From Initiator

_____ 10. Install Shorting Plugs

_____ 11. Remove Mechanism

_____ 12. Repeat 9, 10, & 11 for P. 42

_____ 13. Remove Drogue Release Plate

_____ 14. Remove P. 39 & P. 40 From Initiator (top)

_____ 15. Install Shorting Plugs

_____ 16. Remove P. 37 & P. 58 From Initiator (bottom)

_____ 17. Install Shorting Plugs

YF-16 RPRV PARACHUTE
INSTALLATION CHECKLIST

1. Install main chute in model with arrow on main chute bag pointing up.

2. Bring right and left risers out the tail of the model and run them over the top of the fuselage to the attach points.

3. Tie the front of the main chute bag to the bulkhead of the model with two turns of 100-bl cord.

4. Install four pack opening bands.

YF-16 RPRV/CONTROL VAN
FINAL PREFLIGHT CHECKLIST
(Moring of Flight)

_____ 1. Before closing all hatches, rechecked model for unconnected or loose connectors, loose hardware and general security of the model.

_____ 2. Check that the impact simulation plug has been removed and stowed.

_____ 3. Connect the baro switches (2).

_____ 4. Mount launch rack to back of model and secure (adjustment not necessary yet). Be sure the rack is locked to both hangar assemblies.

_____ 5. Using the umbilical cable, connect the model umbilical plug and the HMS together.

_____ 6. Set up and apply power to the HMS power input plug. The HMS should be in "model power" and the circuit breaker out.

_____ 7. Set up and apply power to the MAIN and AUX battery input plugs - Master Power Switch should be "off".

_____ 8. Remove ADS power warmup cable, stow the time clock arrangement, and set up the warmup cable to be used later.

_____ 9. With the ADS breaker set, connect the onboard ADS power plug to the ADS (will be removed later so don't lock it down).

_____ 10. Energize the HMS circuit breaker, turn on model master power switch, and switch the HMS to "hel power".

_____ 11. Energize all the circuit breakers on the power distribution panel except the L-Band and C-Band transmitters Set the external hydraulic breaker and hydraulic manual switch to "on".

_____ 12. The HMS should show three green lights. Check the PLB monitor circuits.

(a) ARM test
(b) Main umbilical test
(c) Aux umbilical test
(d) Main lanyard test - caution - J110 must not have the flight plug in.
(e) Aux lanyard test - caution - J110 must not have the flight plug installed.

_____ 13. Set up the ground cart for TM reception.

_____ 14. Contact the ground station from the radio truck and prepare to establish the TM link.

_____ 15. Bring all onboard systems up except for C-Band TX and, after good TM has been established, put GMB in "auto" cage. Monitor discrete word #3 on the ground cart for TM information.

_____ 16. Verify operation of the cage - uncage cmds from the control van. After verification, uncage the gyro and leave uncaged for attitude checks on the hook.

_____ 17. Prepare model for hook test - umbilical unraveled, surfaces clear, etc.

_____ 18. Install the alpha protractor and set it to zero.

_____ 19. Cycle the cockpit control into "Emer Con".

_____ 20. Connect launch rack to hook and raise model above dolly several feet to allow attitude changes.

_____ 21. Bring the hydraulic mule up to 1000 psi. Normally the cooling lines won't be necessary, but if any delays are anticipated, they should be employed now.

_____ 22. Accomplish ground station - model link checkout per following checklist items:

_____ (a) Alpha feedback - vane TEU yields stabilizer TED and vice versa. Reset alpha to zero.
_____ (b) Pitch rate feedback - four settings. Stabs should counteract pitching motion.
_____ (c) Roll rate feedback - three settings. Flaps should move in same direction as wingtips.
_____ (d) Yaw rate feedback - three settings. Rudder should move in direction vertical stabilizer moves.
_____ (e) Cycle trim from stop-to-stop on all surfaces to check direction and amount of travel.
_____ (f) Using trim buttons, set the surfaces to model zero; then set the cockpit position indicator zeros.
_____ (g) Step surfaces while checking direction and amount of travel. (cont'd on next page)

(22 (g) cont'd)

Right Roll
Left Roll
Pitchup
Pitch Down
Right Rudder
Left Rudder

_____ 23. Decrease pressure on mule and turn it off.

_____ 24. Move model in the three attitudes while noting that the ADI and model are moving in the same direction.

_____ 25. Lower model back to dolly while noting any activity on the acceleration meter in the cockpit.

_____ 26. Accomplish preflight ADS checks per tables #1 and #3 (model) and #2 and #4 (van) after the cockpit displays have been trimmed up.

	PARA #	12,000 ft	15,000 ft	19,000 ft
		Counts	Counts	Counts
HI ANG STATIC (Zero airspeed)	23			
	PARA #	100 knots	150 knots	200 knots
		Counts	Counts	Counts
LO ANG DYN (Field altitude)	22			

TABLE 1 (MODEL)

	PARA #	12,000 ft	15,000 ft	19,000 ft
		Cockpit	Cockpit	Cockpit
HI ANG STATIC (Zero airspeed)	23			
	PARA #	100 knots	150 knots	200 knots
		Cockpit	Cockpit	Cockpit
LO ANG DYN (Field altitude)	22			

TABLE 2 (VAN)

ALPHA SWITCHOVER VALUE				
	PARA #	3,000 ft	8,000 ft	12,000 ft
		Counts	Counts	Counts
LO ANG STAT (Zero airspeed)	24			
	PARA #	75 knots	125 knots	175 knots
		Counts	Counts	Counts
HI ANG DYN (Field altitude)	21			

TABLE 3 (MODEL)

ALPHA SWITCHOVER VALUE				
	PARA #	3,000 ft	8,000 ft	12,000 ft
		Cockpit	Cockpit	Cockpit
LO ANG STAT (Zero airspeed)	24			
	PARA #	75 knots	125 knots	175 knots
		Cockpit	Cockpit	Cockpit
HI ANG DYN (Field altitudes)	21			

TABLE 4 (JAN)

_____ 27. Remove pitot-static test set and stow.

_____ 28. Complete alpha and beta calibration checks by completing Tables #5 and #6.

NOTE: For beta calibration in the cockpit, alpha must read +60° on cockpit instrument.

ANGLE OF ATTACK PARA # 38		
INPUT	COUNTS	COCKPIT
0		
-5 (TED)		
-10		
0		
5 (TEW)		
10		
15		
20		
30		
40		
50		
60		

TABLE #5

ANGLE OF SIDESLIP PARA # 32		
INPUT	COUNTS	COCKPIT
18 (TEL)		
15		
10		
5		
0		
-5 (TER)		
-10		
-15		
-18		

TABLE #6

_____ 29. Release the "Emer Con" switch in the cockpit.

_____ 30. Cage the gyro from the control van.

_____31. After clearance from the control van, shut down the major model systems, put the GMB into "Man" cage, and switch the AMS to "model" power.

_____32. With the external hydraulic breaker out, reconnect the onboard hydraulic battery connector in the instrumentation bay.

_____33. Disconnect the mule and reconnect the onboard hydraulic system. Operate the system by pushing in the hydraulic circuit breakers and switching the hyd man. on the power distribution box. Listen for unusual noises, vibrations, etc. Check the fluid level after turning off the system with the external circuit breaker - should be between 8 to 10 cubic inches.

_____34. With the HMS in "model" power, turn off the master power switch in the model and pull the circuit breaker on the HMS.

_____35. Disconnect the onboard ADS power plug and reconnect the ADS warmup cable (setup should be ready).

_____36. Disconnect the HMS and stow in ground cart for later steps.

_____37. Close and secure all hatches, except the access panel to the power distribution box.

_____(a) Canopy - be sure top C-Band antenna cable is installed, the main and aux batteries are connected, the nose lift motor connected and all ADS tubes are secure.
_____(b) Instrumentation bay cover - impact plug removed, baros connected, and hydraulic battery power plug connected.
_____(c) Hydraulics bay cover - external hydraulic ports capped, pyro cables secured away from hot or moving parts (actuators), whitey valves open and accumulator charged.
_____(d) Left and right aft fuselage hatches (2).
_____(e) Drogue gun hatch panel and rudder molding halves (2).
_____(f) FWD riser and flaperon actuator access panels (4).

_____38. Check clearance and security of nose compartment. The grounding plug should be installed in J110, but the flight plug should be available.

_____ 39. Remove all foreign material from the dolly (paper, tape, FOD, etc).

_____ 40. Verify that all hatches are installed (except zerk panel) and the risers are taped over.

_____ 41. Assemble the necessary support equipment and prepare to move it to the ramp area:

- _____ (a) ADS warmup batteries and harness on dolly and connected to ADS.
- _____ (b) Launchers and missiles to be used on the dolly.
- _____ (c) "Hel pwr" power supply and power leads for HMS in ground cart.
- _____ (d) HMS and short umbilical interconnect in ground cart.
- _____ (e) Pyro test set and flight plug in ground cart (grounding plug still on bird).
- _____ (f) Zerk panel on dolly.
- _____ (g) Necessary tools and tape (masking and white) in ground cart.
- _____ (h) Welder battery on cart if still at hangar.

_____ 42. Move the model out of the room to the hook in the bay for a tow cable check.

_____ 43. Mount the missiles and launchers on their respective mounts.

_____ 44. Hang the model by the lower umbilical while watching for tight support lines, missing or ripped tape, hang attitude of model, etc.

_____ 45. Transport the model, ground cart, welder cart and light cart to the ramp area for final set up and testing.

_____ 46. Disconnect the ADS warmup cable, reconnect the onboard power plug and lock it.

_____ 47. Move the ADS warmup batteries and setup into the ground cart for storage.

_____ 48. As quickly as possible, apply power to the HMS, set the HMS circuit breaker, reconnect the umbilical between the HMS and model, put HMS into "model" power, turn on the master power switch and switch the HMS into "Hel" power.

(continued on next page)

(48. cont'd)

NOTE: The model is now running off the external power supply, except for the Aux PLB logic - any time the HMS is switched to "model power" the onboard batteries are being run down.

_____ 49. Turn on all the model systems except the L-Band and C-Band transmitters and the external hydraulic breaker.

_____ 50. Remove the grounding plug from J110 and install the pyro test set to J110 to look at PLB outputs.

_____ 51. Reestablish the TM link with the van and accomplish a final launch - fly sequence as follows. Monitor the conditions to be checked off in step 52 during the test.

_____ (a) Input on OZ cmd and hold it at the cockpit. Surfaces remain at zero control light out.

_____ (b) With external hydraulic breaker in, go through launch procedure - pulling the umbilical and the lanyard pins. Hydraulics should turn on and surfaces go to OZ positions after release.

_____ (c) After 3 to 5 seconds, the baro switches will fire the drogue gun. Monitor the sequence with the lights on the pyro test box. After the drogue gun fires, have the cockpit command the main chute immediately.

_____ (d) After the nose lift motor starts and the hydraulics turn off, reset the chute cmd buttons in the control van and confirm that they are off.

_____ (e) When the three cmd lights light again on discrete word #2, reset the lanyard pins and reconnect the umbilical cable.

_____ (f) Cycle the HMS to "hel pwr" and the hydraulics should turn off.

_____ (g) Pull the external hydraulic circuit breaker.

_____ 52. The following control loops <u>must</u> be working:

_____ (a) Flight status lights
Release - lit at release
Control - lit at release, out when drogue fired.
Recovery - no change.

(continued on next page)

(52 cont'd)

_____ (b) Commands from cockpit received by model and acknowledged by cockpit.

_____ Discrete #2 in ground cart showed the model received cmds and shows the commands are reset.

_____ Command lites in cockpit went from "off" to "on" to "off" at reset.

_____ (c) The baro switches (Main and Aux) do initiate recovery sequences. Lights on pyro test set did light.

_____ 53. With all checks completed, get clearance to shut down the model TX from the van.

_____ 54. Turn off L - Band TX to cool the transmitter.

_____ 55. Remove alpha protractor if still installed.

_____ 56. Alpha and Beta vanes should be taped to about neutral position to keep them from spinning. NOTE: Red flag should be attached to boom until tape is removed.

_____ 57. Remove the pyro test box from J110.

_____ 58. With the dummy lanyard pins installed, tape them down.

_____ 59. Making sure the model is clear, carefully insert the flight plug into J110. Everyone within 50 feet should know and understand the model is now armed and dangerous. DO NOT walk behind the model especially.

_____ 60. Wait for chopper arrival. Leave the model powered up (TX off) in "hel" pwr until ready for mating with the helicopter.

_____ 61. After helicopter shutdown, turn off all the main circuit breakers in the model, switch the HMS to "model" pwr and turn off the master pwr switch.

_____ 62. Deliver the HMS and the grounding plug to the LBO in the helicopter for installation.

_____ 63. Move the model into position next to the helicopter and begin the mating checklist.

UH-IN HELICOPTER
CLASS II MODIFICATION EQUIPMENT
INSTALLATION CHECKLIST

NO.	ITEM
1.	Insure winch is securely in place.
2.	Insure all lug fasteners are seated.
3.	Insure ratchet is disengaged.
4.	Inspect upper umbilical:
	a. Clamped at forward gun mount, forward coverplate and oil sump cover.
	b. Quick release disconnect wired to cargo hook well cover.
	c. Sufficient slack provided for the quick disconnect plug.
5.	Bolt guide clamp tightly to rear gun mount.
6.	Attach suspension line knife to convenient tiedown.
7.	Attach oxygen bottles to convenient tiedowns. Insure hoses protected from damage.
8.	Launch control box power connector attached to J100 and taped to floor.
9.	Welder battery secured in left AFT cabin area.
10.	Attach the monofilament hub line (50# test) securely to the winch hub.
11.	Weight of monofilament is 50#.

12.	Attach the braided line (350# test) to the monofilament line.
13.	Wind the monofilament and braided line onto the winch hub such that no more than two (2) feet of braided line is wound onto the hub.

YF-16 RPRV/UH-IN HELICOPTER
MATING CHECKLIST

______ 1. Install launch box to upper umbilical and to welder battery power source.

______ 2. Check location of following switches on launch box.

 ______ a. Launch switch down and guard closed.

 ______ b. ARM TEST switch up.

 ______ c. Power select switch in "model power."

 ______ d. Circuit breaker out.

______ 3. Launch cable connected to cargo hook.

______ 4. Lower umbilical connected to upper umbilical quick release plug.

______ 5. After checking to see that the orange band shows on quick release plug, tug on the lower umbilical plug and note smooth separation of the quick release plug.

______ 6. Reinstall the lower umbilical to the upper umbilical. Check for orange band.

______ 7. Push in the circuit breaker on the launch box - disregard any lights. The welder battery monitor meter should show 30 VDC or greater.

______ 8. Check launch rack to insure it is still secure to model.

______ 9. Insure the dummy lanyard pins are installed and taped.

______ 10. While maintaining pull on the launch rack, cycle the launch switch on the launch box. The rack should separate smoothly from the model and the attachment hooks fall flush to skin of model.

______ 11. Reinstall the launch rack to the model, but leave the umbilical plug disconnected.

______ 12. With the imbilical disconnected from the model, disconnect the welder battery and connect the launch box to helicopter bus power.

______ 13. Turn on the helicopter master switch and necessary circuit breakers.

______ 14. Launch box meter should show 24 VDC or greater and three yellow and one red light with launch switch reset.

______ 15. Maintaining pull on the launch rack, cycle the launch switch again. The rack should come away smoothly and then all the launch box lights go out.

______ 16. Close the guard on the launch switch and safety wire.

______ 17. Reinstall the launch rack and tighten the sway braces.

______ 18. Connect the umbilical plug to the model and check that the orange band is clearly visible for about 1/16-inch.

______ 19. Disconnect the helicopter buss power cable to the launch box and reconnect the welder battery.

______ 20. With the launch box in "model power," turn on the master power switch in the model. Launch box lights should show three green.

_____ 21. Switch the launch box to "hel pwr".

_____ 22. Turn on all the systems in the model except the L-Band TX and the external hydraulic breaker.

_____ 23. Maintain pull on the tow cable at the cargo hook.

_____ 24. Cycle the cargo jettison switch in the helicopter.

_____ 25. Ensure the cable separates smoothly from the cargo hook, leave umbilical plugs connected.

_____ 26. Turn the helicopter master switch off.

_____ 27. Reattach the tow cable to the cargo hook.

_____ 28. Maintain pull on the tow cable at the cargo hook.

_____ 29. Cycle the manual release for the cargo hook and check for smooth operation of the separation.

_____ 30. Reattach the tow cable to the cargo hook and assure the cargo hook is locked by tugging on the tow cable.

_____ 31. Check for the orange band showing on the umbilical plugs at both the cargo hook and the model - approximately 1/16-inch.

_____ 32. Attach the lanyard pull line to the cargo tiedown next to the winch.

_____ 33. Attach the reefer line to the braided line at the winch.

_____ 34. Position the cable around the skids at the rear of the helicopter.

_____ 35. Tape the clevises on the launch rack so they won't tuck under accidentally.

_____ 36. Test operation of the monitor circuits on the launch box as follows:

- _____ a. Cycle ARM TEST switch down; green light out and yellow light on.
- _____ b. Reset ARM TEST switch up; green light on and yellow light out.
- _____ c. Cycle umbilical test switch both directions; green light out and yellow light on in "up" and "down" positions.
- _____ d. Remove <u>one</u> dummy lanyard pin; green light out and yellow light on.
- _____ e. Replace the lanyard pin with the real pin attached to the launch rack; yellow light out and green light on.
- _____ f. Remove the second <u>dummy</u> lanyard pin; green light out and yellow light on.
- _____ g. Install the second <u>real</u> lanyard pin attached to the launch rack; yellow light out and green light on.

_____ 37. Push in the L-Band TX circuit breaker and the external hydraulic circuit breaker. Hydraulics should <u>not</u> come on.

_____ 38. Verify model surfaces are at zero by cycling the launch box into "model power" and then back to "hel power". Note the "main" and "aux" battery voltages while loaded.

_____ 39. Switch "Gyro Monitor Box" to "auto" cage and have the control van uncage the gyro.

_____ 40. Recage the gyro from the control van, leave GMB in "auto" cage.

_____ 41. Make sure all the circuit breakers on the power distribution box are set.

_____ 42. Install the "zerk" panel and secure.

_____ 43. Remove the drogue gun shield.

_____ 44. Remove the tape from the nose boom.

_____ 45. Clear the helicopter for engine start.

_____ 46. Pull the nose down after the model is lifted from the cradle.

_____ 47. Watch the clevices on the launch rack so they don't tack under.

UH-IN HELICOPTER/YF-16 RPRV
IN-FLIGHT TOW PROCEDURES CHECKLIST

FLIGHT ________ TAKEOFF TIME ________

DATE ________ RANGE TIME ________

OPS NO. ________ MISSION FREQ ________

CALL SIGNS:

RICK ____	UH-1N Tow Helicopter
RICK ____	Control Van (Model Pilot)
RICK ____	A-37B Safety/Photo Chase
DATA ____	Data Room (Test Director)
PAPA CHARLIE	Mobile Ground Station
SPORT	Sport Radar Control
DOWNFALL	Range Control

ACC - Model Assistant Crew Chief:
HCC - Helicopter Crew Chief or Marshaller:
HM - Helicopter Mechanic:
HP - Helicopter Pilot:
LBO - Launcher Box Operator:
MP - Model Pilot:
RC - Radar Controller:
SC - Safety Chase Pilot:
SM - Systems Monitor
TD - Test Director:
TE - Test Engineer:
DRM - Data Room Monitor:

RESPONSIBLE INDIVIDUAL	
HP	1. Depart the ramp at takeoff time and taxi to ramp area north of Bldg. 1830.
HP	2. Prior to shutdown at Bldg. 1830, accomplish radio check with Control Van and mobile ground station on mission frequency. Give Control Van current altimeter setting and altitude check at ground level. Give helicopter magnetic heading.

RESPONSIBLE INDIVIDUAL	
TE	Altimeter Setting ______ Altitude ______ Heading ______
TE	3. Set Altimeter. to field altitude(2300')
	4. Slave Altimeter to read model altitude. The following procedures will be accomplished in the Control Van while mating of model and helicopter is being accomplished.
TE	5. Check Test Engineer's Panel

a. Pitch axis flight control mode. ______

b. Roll axis flight control mode. ______

c. Yaw axis flight control mode. ______

d. Other flight control modes - as desired. ______

e. All other Flight Control Mode Select Buttons - Out (Red showing).

f. Automatic Spin Recovery Button - Out. (red showing).

g. Autopilot Disengage Button - Out. (red showing).

h. Flight/Simulate Mode Switch - Flight.

RESPONSIBLE INDIVIDUAL		
	j.	Gyro Switch - Cage.
	k.	Emergency Control Switch - Cover Dwn.
	l.	Pitch RD-3 Potentiometer - Set.
	m.	Roll RD-3 Potentiometer - Set.
	n.	Yaw RD-3 Potentiometer - Set.
MP	6.	Check Model Pilot's Station Switches.
or ET	a.	Emergency Parachute Deployment Switch - Cover down and safety wire fastened.
	b.	Pyro Arm Button - Out
	c.	Drogue Deploy Button - Out
	d.	Main Deploy Button - Out
	e.	Plastic cover for Manual Deployment Buttons - Down & fastened.
	f.	Control Stick Select Switch - Center.
TE	7.	After model ground crew aligns model with helicopter heading, test engineer (TE) will slew ADI to indicate correct helicopter heading.
HP & TE	8.	After restarting engine and before liftoff, helicopter pilot will coordinate with TE. TE will uncage gyro.

RESPONSIBLE INDIVIDUAL		
LBO	9.	Launch box operator (LBO) monitors launch control box at all times for unsafe towing condition.
HM	10.	Helicopter Mechanic (HM) will monitor the motions of the model at all times.
HP HCC	11.	After lift-off, hover with the model apporximately four feet above the ground. Helicopter crew chief or marshaller will assist as necessary.
ACC	12.	Model assistant crew chief will lower nose boom of model.
HP	13.	Helicopter will depart ramp area for PIRA.
HP	14.	After handoff from tower, pilot will contact Sport on mission freq. for radar contact. Establish 55 KIAS climb airspeed.
HP	15.	Pilot will contact Downfall on mission freq prior to entry into PIRA.
HP	16.	Pilot will continue climb as soon as tower clears altitude.
RC	17.	Sport Control will vector helicopter to precomputed launch point over planned ground track.
HP	18.	Ascend to 18,500 ft or highest attainable altitude using best climb rate.
HP	19.	Call altitude every 2,000 ft.

RESPONSIBLE INDIVIDUAL		
SC	20.	Chase will stay below helicopter and clear of the model launch trajectory.
HP	21.	Sport Control will call time to launch at 2 minutes, 1 minute, 30 seconds, and 15 seconds prior to launch window.
TE	22.	At 1 minute prior to launch window, cycle Flight/Simulate Mode Switch to Simulate and back to Flight. Remind Model Pilot to leave control stick neutral until clearance to launch is broadcast on UHF.
HP	23.	At 1 minute prior to launch window, helicopter pilot will report his magnetic heading to the model pilot and test engineer.
TE	24.	At 1 minute prior to launch window, Test Engineer will check ADI for correct magnetic heading, 10 degrees nose down, wings level attitude.
TE	25.	If necessary, Test Engineer will cage gyro, reset ADI, and uncage gyro.
LBO	26.	After gyro is checked, LBO will switch to model power. Monitor main and auxiliary battery voltage on launch box. If either is below 28.0 volts, launch will be aborted.
LBO	27.	At 15 seconds prior to launch, select and hold control surface test on launch box (spring loaded switch).

RESPONSIBLE INDIVIDUAL		
TE & DRM	28.	Observe displacement of angle of attack and proper response of elevator commands and positions on data recorders and cockpit instruments.
TD	29.	At conclusion of control surface test, Director will give final clearance for launch on UHF.
SC	30.	After getting clearance from Test Director, Safety Chase Pilot will call "Five Seconds to Launch" when in best position.
LBO	31.	After receiving final clearance for launch from Test Director and "Five-Second" call from Chase Pilot, LBO will silently count down 5 sec and launch model.
HM & LBO	32.	HM & LBO will reef launch rack into helicopter. Advise pilot when rack is inside helicopter.
SC	33.	Chase should avoid crossing directly behind the model, and if so, insure separation distance of at least 500 ft.
SC	34.	If a lakebed landing is called, chase will assist model pilot as briefed.
HP	35.	Helicopter will pick up drogue and pilot chute. Chase will direct helicopter to drogue chute impact point.
HP	36.	Land near model.
LBO	37.	Pull external Hyd C/B on model.

RESPONSIBLE INDIVIDUAL		
LBO	38.	If possible, install pyro shorting plug in nose of model.
LBO	39.	Remove zerk panel and turn off master power switch.
HP	40.	Helicopter will assist recovery crew to model landing site.

UH-1N HELICOPTER/YF-16 RPRV
EMERGENCY PROCEDURES

1. EMERGENCY LAUNCH/JETTISON

a. If time permits, helicopter pilot will call for emergency launch in 10 seconds. Data systems and cameras will be turned on. Test engineer will uncage gyro.

b. If time permits, LBO will launch model from launch box.

c. Helicopter pilot will jettison cargo from cargo hook.

2. UNSAFE TOWING CONDITION

a. If at any time a yellow warning light appears on the launch control box, and 10,000 ft altitude has not been reached, the mission will be aborted and the helicopter will proceed to the abort area. LBO will disconnect lanyard pull line from tiedown ring and activate nose ligt switch. Place model on ground and jettison from cargo hook. DO NOT LAUNCH THE MODEL FROM THE LAUNCH BOX. Land near by, where the LBO will go to the model and pull the external hydraulic C/B, install pyro shorting plug in nose of model, and remove zerk panel and turn off master power switch. Keep spectators away.

b. If at any time TWO yellow warning lights appear simultaneously on the launch control box, and the altitude of the helicopter is above 6000 feet, the model will be prepared for launch. Refer to EMERGENCY LAUNCH/JETTISON procedure.

c. If at any time all three yellow warning lights, or the red light appears on the

launch control box, the LBO will IMMEDIATELY launch the model. At the same time, he will alert the pilot that the red light is on. If the pilot has not sensed the launch of the payload by the time he is verbally warned, he will jettison the cargo. Test engineer will uncage gyro at first warning of emergency launch or jettison.

3. FAILUTE TO DAMP OSCILLATIONS

   a. Refer to EMERGENCY LAUNCH/JETTISON procedure. If cable becomes stable, LBO will reef cable inside.

   b. If launch mechanism is unstable, disconnect lanyard pull line and jettison launch mechanism.

4. HELICOPTER EMERGENCY

   a. If sufficient time is available, disconnect lanyard pull line, activate nose lift switch, and descend and place the model on the ground. Jettison the model from the cargo hook.

   b. If time is critical, refer to EMERGENCY LAUNCH/JETTISON procedure.

   c. Reef cable inside helicopter.

5. MODEL HYDRAULICS LOCKED ON

   a. Turn off RF from control van.

   b. If no response, advise pilot to land model immediately.

   c. Follow procedure for UNSAFE TOWING CONDITION

6. CONTROL SURFACE CREEP

   a. Switch to model power on launch box. Return switch to helicopter power after 4 seconds.

STALL/SPIN DROP MODEL

FLIGHT 2-D-1

HANDLING QUALITIES AND AERODYNAMIC DERIVATIVES

Model Configuration: Leading Edge Flaps - 30 deg down
CG at 35% MAC

Flight Control System Gains: K_α = 0.4 deg/deg
K_p = 0.18 deg/deg/sec
K_q = 0.6 deg/deg/sec
K_r = 0.045 deg/deg/sec

EVENT	CONDITIONS	APPROXIMATE EVENT COMPLETION ALTITUDE (ft MSL)
1. Launch	$\psi = 255^\circ$ Mag	18,500
2. Stabilize from launch transients		17,500
3. Establish trim conditions	$\alpha = 14^\circ$ (106 KIAS)	16,800
4. Bank to bank rolls	V_i = 106 KIAS $\phi_{max} = \pm 20^\circ$	16,000
5. Restabilize on trim conditions	$\alpha = 14^\circ$ (106 KIAS)	15,900
6. Left turn to $\psi = 225^\circ$ Mag	V_i = 106 KIAS $\phi = -20^\circ$	15,600
7. Restabilize on trim conditions	$\alpha = 14^\circ$ (106 KIAS)	15,500
8. Push-over pull-up	$\alpha = 14^\circ\ 8^\circ\ 14^\circ\ 11^\circ$	15,000
9. Establish trim conditions	$\alpha = 11^\circ$ (122 KIAS)	14,900
10. Left turn to $\psi = 165^\circ$ Mag	V_i = 122 KIAS $\phi = -40^\circ$	14,300
11. Restabilized on trim conditions	$\alpha = 11^\circ$ (122 KIAS)	14,200
12. Right turn to $\psi = 255^\circ$ Mag	V_i = 122 KIAS $\phi = +60^\circ$	13,300
13. Restabilize on trim conditions	$\alpha = 11^\circ$ (122 KIAS)	12,900
14. Left aileron roll	ϕ = 90 deg/sec	12,000
15. Establish trim conditions	$\alpha = 8^\circ$ (148 KIAS)	11,500
16. Yaw doublet	$\alpha = 8^\circ$ (148 KIAS) $\delta_r = -10^\circ, +10^\circ$	11,300
17. Pitch doublet	$\alpha = 8^\circ$ (148 KIAS) $\delta_e = -2^\circ, +2^\circ$	10,900
18. Establish trim conditions	$\alpha = 11^\circ$ (122 KIAS)	10,500
19. Yaw doublet	$\alpha = 11^\circ$ (122 KIAS) $\delta_r = -10^\circ, +10^\circ$	10,300
20. Pitch doublet	$\alpha = 11^\circ$ (122 KIAS) $\delta_e = -2^\circ, +2^\circ$	10,000

EVENT	CONDITION	APPROXIMATE EVENT COMPLETION ALTITUDE (ft MSL)
21. Establish trim conditions	$\alpha = 14^o$ (106 KIAS)	9,600
22. Steady State Side Slip	$\alpha = 14^o$ (106 KIAS) $\beta = +3^o$	9,300
23. Yaw doublet	$\alpha = 14^o$ (106 KIAS) $\delta_r = -10^o, +10^o$	9,100
24. Pitch doublet	$\alpha = 14^o$ (106 KIAS) $\delta_e = -2^o, +2^o$	8,700
25. Establish trim conditions	$\alpha = 18^o$ (92 KIAS)	8,200
26. Yaw doublet	$\alpha = 18^o$ (92 KIAS) $\delta_r = -10^o, +10^o$	7,900
27. Roll doublet	$\alpha = 18^o$ (92 KIAS) $\delta_{fa} = -5^o, +5^o$	7,600
28. Pitch doublet	$\alpha = 18^o$ (92 KIAS) $\delta_e = +2^o, -2^o$	7,200
29. Restabilize on trim conditions	$\alpha = 18^o$ (92 KIAS)	6,600
30. Yaw doublet	$\alpha = 18^o$ (92 KIAS) $\delta_r = -10^o, +10^o$	6,300
31. Roll doublet	$\alpha = 18^o$ (92 KIAS) $\delta_{fa} = -5^o, +5^o$	6,000
32. Pitch doublet	$\alpha = 18^o$ (92 KIAS) $\delta_e = +2^o, -2^o$	5,500

EVENT	CONDITION	APPROXIMATE EVENT COMPLETION ALTITUDE (ft MSL)
33. Automatic parachute deployment sequence begins	h_p = 5,500 ft MSL	5,500

STALL/SPIN DROP MODEL

FLIGHT 3-D-2

HANDLING QUALITIES AND AERODYNAMIC DERIVATIVES

Model Configuration: Leading Edge Flaps - 30 deg down cg at 35.5%

Flight Control System Gains:
K_α = 0.4 deg/deg
K_p = 0.18 deg/deg/sec
K_q = 0.6 deg/deg/sec
K_r = 0.045 deg/deg/sec

EVENT	CONDITIONS	APPROXIMATE EVENT COMPLETION ALTITUDE (FT MSL)
1. Launch	ψ = 255° Mag	18,000
2. Stabilize from launch transient		16,300
3. Establish trim conditions	α = 14° (110 KIAS)	15,700
4. Roll evaluation	V_i = 110 KIAS ϕ = 0°→-20°→+20°→0°	15,200
5. Reestablish trim conditions	α = 14° (110 KIAS)	14,800
6. Rudder doublet	α = 14° (110 KIAS) δ_r = -10°, +10°	14,700
7. Elevator doublet	α = 14° (110 KIAS) δ_e = -2°, +2°	14,600
8. Reestablish trim conditions	α = 14° (110 KIAS)	14,400

EVENT	CONDITIONS	APPROXIMATE EVENT COMPLETION ALTITUDE (FT MSL)
9. Steady state sideslip	α = 14° (110 KIAS) β = +3°	14,000
10. Left turn to ψ = 225° Mag	V_i = 110 KIAS ϕ = -20°	13,300
11. Pushover pullup	α = 14°→8°→14°→11°	13,000
12. Establish trim conditions	α = 11° (120 KIAS)	12,600
13. Rudder doublet	α = 11° (120 KIAS) δ_r = -10°, +10°	12,300
14. Elevator doublet	α = 11° (120 KIAS) δ_e = -2°, +2°	12,000
15. Left turn to ψ = 165° Mag	V_i = 120 KIAS ϕ = -40°	11,300
16. Reestablish trim conditions	α = 11° (120 KIAS)	11,000
17. Right turn to ψ = 255°	V_i = 120 KIAS ϕ = +60°	10,500
18. Reestablish trim conditions	α = 11° (120 KIAS)	10,300
19. Left aileron roll	$\dot{\phi}$ = 90 deg/sec	9,400
20. Establish trim conditions	α = 8° (150 KIAS)	8,900
21. Rudder doublet	α = 8° (150 KIAS) δ_r = -10°, +10°	8,700

EVENT		CONDITIONS	APPROXIMATE EVENT COMPLETION ALTITUDE (FT MSL)
22.	Elevator doublet	α = 8° (150 KIAS) δ_e = +2°, -2°	8,500
23.	Establish trim conditions	α = 18° (95 KIAS)	7,500
24.	Rudder doublet	α = 18° (95 KIAS) δ_r = -10°, +10°	7,300
25.	Aileron doublet	α = 18° (95 KIAS) δ_{fa} = -5°, +5°	7,200
26.	Elevator doublet	α = 18° (95 KIAS) δ_e = -2°, +2°	7,000
27.	Reestablish trim conditions	α = 18° (95 KIAS)	6,800
28.	Rudder doublet	α = 18° (95 KIAS) δ_r = -10°, +10°	6,600
29.	Aileron doublet	α = 18° (95 KIAS) δ_{fa} = -5°, +5°	6,400
30.	Elevator doublet	α = 18° (95 KIAS) δ_e = -2°, +2°	6,200
31.	Automatic parachute deployment sequence begins		6,000

STALL/SPIN DROP MODEL

FLIGHT 3-D-3
FLYING QUALITIES AND AERODYNAMICS DERIVATIVES EXTRACTION

Model Configuration: Leading Edge Flaps at - 25 deg.
CG at 34.8% MAC

Flight Control System Gains: K_α = 0.4 deg/deg
K_p = 0.18 deg/deg/sec
K_q = 0.6 deg/deg/sec
K_r = 0.045 deg/deg/sec

EVENT	CONDITIONS	APPROXIMATE EVENT COMPLETION ALTITUDE (FT MSL)
1. Launch	$\psi = 200^\circ$ Mag Hdg	18,000
2. Stabilized from launch transient		16,300
3. Trim Shot	150 KIAS ($\alpha = 8\frac{1}{2}^\circ$)	15,700
4. Rudder Doublet	$\delta_r = -10^\circ, +10^\circ$	14,600
5. Aileron Doublet	$\delta_a = -5^\circ, +5^\circ$	14,450
6. Stabilator Doublet	$\delta_s = -2^\circ, +2^\circ$	14,200
7. Trim Shot	130 KIAS ($\alpha \simeq 11^\circ$)	13,600
8. Rudder Doublet	$\delta_r = -10^\circ, +10^\circ$	12,800
9. Aileron Doublet	$\delta_a = -5^\circ, +5^\circ$	12,600
10. Stabilator Doublet	$\delta_s = -2^\circ, +2^\circ$	12,400

EVENT	CONDITIONS	APPROXIMATE EVENT COMPLETION ALTITUDE (FT MSL)
11. Steady Sideslip	$\phi = 0^\circ, \beta = -3^\circ$	12,100
12. Steady Sideslip	$\phi = 0^\circ, \beta = +3^\circ$	11,500
13. Bank Turns	$\phi = -30^\circ, +30^\circ$	10,600
14. Trim Shot	110 KIAS ($\alpha \simeq 18^\circ$)	10,000
15. Rudder Doublet	$\delta_r = -10^\circ, +10^\circ$	9,100
16. Aileron Doublet	$\delta_a = -5^\circ, +5^\circ$	8,950
17. Stabilator Doublet	$\delta_s = -2^\circ, +2^\circ$	8,750
18. Trim Shot	100 KIAS ($\alpha \simeq 18^\circ$)	7,500
19. Rudder Doublet	$\delta_r = -10^\circ, +10^\circ$	6,750
20. Aileron Doublet	$\delta_a = -5^\circ, +5^\circ$	6,650
21. Stabilator Doublet	$\delta_s = -2^\circ, +2^\circ$	6,500
22. Automatic Parachute deployment sequence begins		6,000

YF-16 REMOTELY PILOTED RESEARCH VEHICLE
MODEL EMERGENCY PROCEDURES

EMERGENCY LAUNCH/JETTISON

1. GYRO UNCAGE AT FIRST INDICATION OF EMERGENCY LAUNCH OR JETTISON

If model jettisoned

2. PYRO ARM BUTTON AND DROGUE DEPLOY BUTTON-DEPRESS SIMULTANEOUSLY

3. MODEL STABILIZED UNDER DROGUE CHUTE, MAIN DEPLOY BUTTON - DEPRESS

If model launched

4. Stabilize on 120 KIAS, not exceeding 20 degrees angle-of-attack.

5. Above 100 KIAS, begin 40° banked turn to heading to PB-8.

6. If altitude at or below minimum for glide to PB-8, attain 140 KIAS for best angle of glide to 6,000 feet MSL.

7. If altitude above minimum for glide to PB-8, accomplish planned flight test events until leading glide profile altitude or 6,000 feet MSL

8. At 6,000 feet MSL, accomplish manual parachute deployment procedure.

MODEL OUT OF CONTROL/DEPARTURE/SPIN

1. RELAX CONTROL, IDENTIFY MANEUVER

2. IF SPIN IDENTIFIED, STICK - FULL WITH SPIN (TURN NEEDLE AND YAW DIRECTION)

3. RUDDER - FULL OPPOSITE STICK, TURN NEEDLE AND YAW DIRECTIONS

4. AT AOA BELOW 20°, NEUTRALIZE CONTROLS AND RECOVER

5. IF OUT OF CONTROL THROUGH 10,000 FEET MSL, INITIATE MANUAL PARACHUTE DEPLOYMENT PROCEDURE

MANUAL PARACHUTE DEPLOYMENT

1. PYRO ARM BUTTON AND DROGUE DEPLOY BUTTON - DEPRESS SIMULTANEOUSLY

2. MODEL STABILIZED UNDER DROGUE CHUTE AND ALTITUDE BELOW 10,000 FEET MSL, MAIN DEPLOY BUTTON - DEPRESS

EMERGENCY PARACHUTE DEPLOYMENT

1. EMERGENCY PARACHUTE DEPLOYMENT SWITCH - LIFT COVER AND ACTIVATE SWITCH

LAKEBED LANDING

1. MAINTAIN 140 KIAS UNTIL INITIATION OF ROUNDOUT

2. Chase will give heading corrections and altitude above ground information to model pilot

3. Test engineer will monitor altitude requirements and will call gross heading changes to adjust altitude as necessary

4. Chase will call estimated altitudes continuously below 100 feet AGL

LOSS OF DOWNLINK

1. If loss of downlink persists continuously for 10 seconds or more, or if model goes out of control, or if altitude goes below 10,000 feet MSL, initiate manual parachute deployment procedure

LOSS OF UPLINK

1. If loss of uplink persists continuously for 10 seconds or more, or if model goes out of control, or if altitude goes below 10,000 feet MSL, initiate emergency parachute deployment procedure

UPLINK TRANSMITTER FAILURE

1. Emergency parachute deployment

COMPUTER FAILURE

1. Emergency parachute deployment

AIRSPEED INDICATOR FAILURE

1. Avoid rapid control inputs or extreme attitudes
2. Stabilize at 8° to 11° AOA
3. Perform stability maneuvers between 8° and 14° AOA as altitude permits

AOA INDICATOR FAILURE

1. Avoid rapid control inputs or extreme attitudes
2. Stabilize at 120 to 140 KIAS
3. Perform stability maneuvers between 120 and 160 KIAS as altitude permits

ATTITUDE INDICATOR FAILURE

1. Initiate manual parachute deployment procedure

YF-16 RPRV
RECOVERY TEAM CHECKLIST

1. EOD (Explosive Ordance Disposal) contact TSgt Bailey at 72162, 2-3 days prior to Flt.
2. Radio truck/comm contact Maj Barrett.
3. One and one-half ton recovery truck contact motor pool 1-2 days prior to flight at 72741.
4. Range truck w/hoist contact Mr Munson at 32603 or call 32633/Bldg. 9505.
5. Photo lab/still color pictures contact Center Sched at 74110/74112.
6. Parachute shop - recovery of chute.

YF-16 RPRV
RECOVERY TEAM CHECKLIST

1. Recovery team will group at Bldg. 9505, Pyro Road Rocket Lab approx. ________ before scheduled drop.
2. At the confirmation of Mr Munson (Range Director) of a completed launch and impact, proceed to PB-8.
3. Lpaction of model will be coordinated between radio truck of recovery team and launch helicopter.
4. First to approach and contact model will be the EOD (Explosive Ordance Disposal) personnel to disarm any live pyrotechnic devices.
5. Second to contact model will be Sgt Bell to shut off hyd pwr (if necessary), and a representative of the parachute shop, to recover and pack the recovery chute.
6. Recovery of model and all procedures concerning the hoisting process and tiedown procedure will be coordinated thru Sgt Bell and or representatives from R&D Instrumentation.

LIST OF ABBREVIATIONS AND SYMBOLS

Item	Definition	Units
ADI	attitude director indicator	---
ADS	air data system	---
AFFDL	Air Force Flight Dynamics Laboratory	---
AFFTC	Air Force Flight Test Center	---
AIU	airborne interface unit	---
A&M	Atkins & Merrill, Incorporated	---
b	wingspan	in.
bl	model buttocks line	in.
$\bar{c}$	length of the MAC	in.
C_c	chord force coefficient	dimensionless
C_c'	chord force coefficient, estimated value	dimensionless
C_D	total drag coefficient	dimensionless
C_D'	total drag coefficient, estimated value	dimensionless
C_ℓ	rolling moment coefficient	dimensionless
C_L	total lift coefficient	dimensionless
C_L'	total lift coefficient, estimated value	dimensionless
C_{ℓ_p}	$\partial C_\ell/\partial(pb/2V_t)$	per radian
C_{ℓ_r}	$\partial C_\ell/\partial(rb/2V_t)$	per radian
C_{ℓ_β}	$\partial C_\ell/\partial\beta$	per degree
$C_{\ell_{\delta_a}}$	$\partial C_\ell/\partial\delta_a$	per degree
$C_{\ell_{\delta_r}}$	$\partial C_\ell/\partial\delta_r$	per degree
C_m	pitching moment coefficient	dimensionless

Item	Definition	Units
C_{m_q}	$\partial C_m/\partial(q\bar{c}/2V_t)$	per radian
C_{m_α}	$\partial C_m/\partial\alpha$	per degree
$C_{m_{\delta_e}}$	$\partial C_m/\partial\delta_e$	per degree
C_n	yawing moment coefficient	dimensionless
C_N	normal force coefficient	dimensionless
C_{n_p}	$\partial C_n/\partial(pb/2V_t)$	per radian
C_{n_r}	$\partial C_n/\partial(rb/2V_t)$	per radian
C_{N_α}	$\partial C_N/\partial\alpha$	per degree
C_{n_β}	$\partial C_n/\partial\beta$	per degree
$C_{n_{\delta_a}}$	$\partial C_n/\partial\delta_a$	per degree
$C_{N_{\delta_e}}$	$\partial C_N/\partial\delta_e$	per degree
$C_{n_{\delta_r}}$	$\partial C_n/\partial\delta_r$	per degree
C_y	side force coefficient	dimensionless
C_{y_β}	$\partial C_y/\partial\beta$	per degree
cg	center of gravity	percent MAC
db	decibel	---
dc	direct current	---
deg	degrees	---
dh/dt	rate of decent	feet per second
DMAC	direct memory access console	---
EOD	explosive ordnance disposal	---
fps	feet per second	---
fs	model fuselage station	in.
g	acceleration due to gravity	32.174 ft per sec
GFE	government furnished equipment	---

Item	Definition	Unit
Hz	Hertz (one cycle per second)	---
I_{xx}	moment of inertia about the x axis	slug-ft^2
I_{xz}	product of inertia about the x and z axes	slug-ft^2
I_{yy}	moment of inertia about the y axis	slug-ft^2
I_{zz}	moment of inertia about the z axis	slug-ft^2
IC	integrated circuit	---
K_p	roll rate feedback gain	deg/deg/sec
K_q	pitch rate feedback gain	deg/deg/sec
K_r	yaw rate feedback gain	deg/deg/sec
K_α	angle of attack feedback gain	deg/deg
KCAS	knots calibrated airspeed	---
KIAS	knots indicated airspeed	---
lb	pound, pounds	---
LBO	launch box operator	---
LEF	leading edge flaps	---
LVDT	linear variable differential transformer	---
M	flight mach number	---
MAC	mean aerodynamic chord	in.
MHz	megahertz (10^6 cycles per second)	---
MLB	model monitor/launch box	---
MMLE	modified maximum likelihood estimator	---
MSL	mean sea level	---
n_x	load factor along the body x axis	dimensionless
n_z	load factor opposite to the body z axis	dimensionless
NASA/ DFRC	National Aeronautics and Space Administration/Dryden Flight Research Center	---

Item	Definition	Units
p	roll rate	deg per sec
PB-8	precision bombing target number 8	---
PCM	pulse code modulation	---
PIRA	Precision Impact Range Area	---
PLB	parachute logic box	---
psf	pounds per square foot	---
psig	pounds per square inch, guage	---
q	pitch rate	deg per sec
$\bar{q}$	dynamic pressure	lb per ft^2
q_c	differential pressure	lb per ft^2
r	yaw rate	deg per sec
RPRV	remotely piloted research vehicle	---
S	wing area	ft^2
sec	second (of time)	---
SPORT	Space Positioning Optical Radar Tracking	---
TED	trailing edge down	---
TEU	trailing edge up	---
UHF	ultra high frequency	---
V_t	true airspeed	ft per sec
VVI	vertical velocity indicator	---
W	model gross weight	lb
wl	model water line	in.
α	angle of attack	deg
β	angle of sideslip	deg
γ	flightpath angle, angle of inclination of the flightpath from the horizontal plane	deg
δ_a	total aileron deflection	deg
δ_e	total elevator deflection	deg

Unit	Definition	Units
δ_r	rudder deflection	deg
θ	pitch angle	deg
ν	kinematic viscosity	ft^2 per sec
ν_o	kinematic viscosity at sea level, standard day	1.5665×10^{-4} ft^2 per sec
σ	ratio of local air density to that of sea level	dimensionless
ϕ	bank angle	deg
ϕ_a	average bank angle during maneuver	deg
ψ	heading angle	deg

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